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PROGRAM FOR THE DESIGN OF AN AXIAL COMPRESSOR STAGE BASED ON THE RADIAL EQUILIBRIUM EQUATIONS

by

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Abstract:

A computer program is presented to determine the three-dimensional flow conditions in an axial flow compressor stage. Entropy and energy gradients are taken into account as well as the radial shift and the curvatures of the axisymmetric stream surfaces. The program can be used at elevated Mach numbers since shock losses and compressibility effects are included. It represents an extension of work done for a research program to investigate the tip clearance effects in a three-stage compressor, supported by:

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PROGRAM FOR THE DESIGN OF AN AXIAL COMPRESSOR STAGE BASED ON THE RADIAL EQUILIBRIUM EQUATIONS

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1. Introduction

The present report describes a program which has been established for the design of an axial flow compressor intermediate stage using the radial equilibrium equations as described in ref. 1 (pages 439 - 454). An intermediate stage is defined as one for which inlet and outlet velocities are essentially the same.

The flow is assumed compressible and axisymmetric. The inlet conditions, some of which are data to the program, are assumed to have been produced in preceding stages and are referred to ambient conditions). Energy gradients at the inlet, which may be caused by non-uniform energy addition in previous stages, as well as entropy gradients at the inlet, which may be due to non-uniform energy dissipation in previous stages, are taken into account.

The losses and the corresponding entropy increase through the rotor and the stator are calculated according to reference 3, and non-uniform energy increase in the rotor can be specified.

The inner and outer walls may have arbitrary shape. However, when the curvature of the streamlines (in the way described in reference 1.) is taken into account, then the inner and outer walls, although maybe tapered, have to be straight.

The problem is considered from the designer's point of view. Consequently, specified will be the work distribution, and the quantity $\frac{V_{u_1}+V_{u_2}}{u_1+u_2}$ will be specified along the radius (see symbol table for symbols). The quantity $\frac{V_{u_1}+V_{u_2}}{u_1+u_2}$ gives the theoretical reaction factor for an intermediate stage with constant axial velocity for incompressible flow. This quantity was chosen instead of the actual reaction factor as the expression

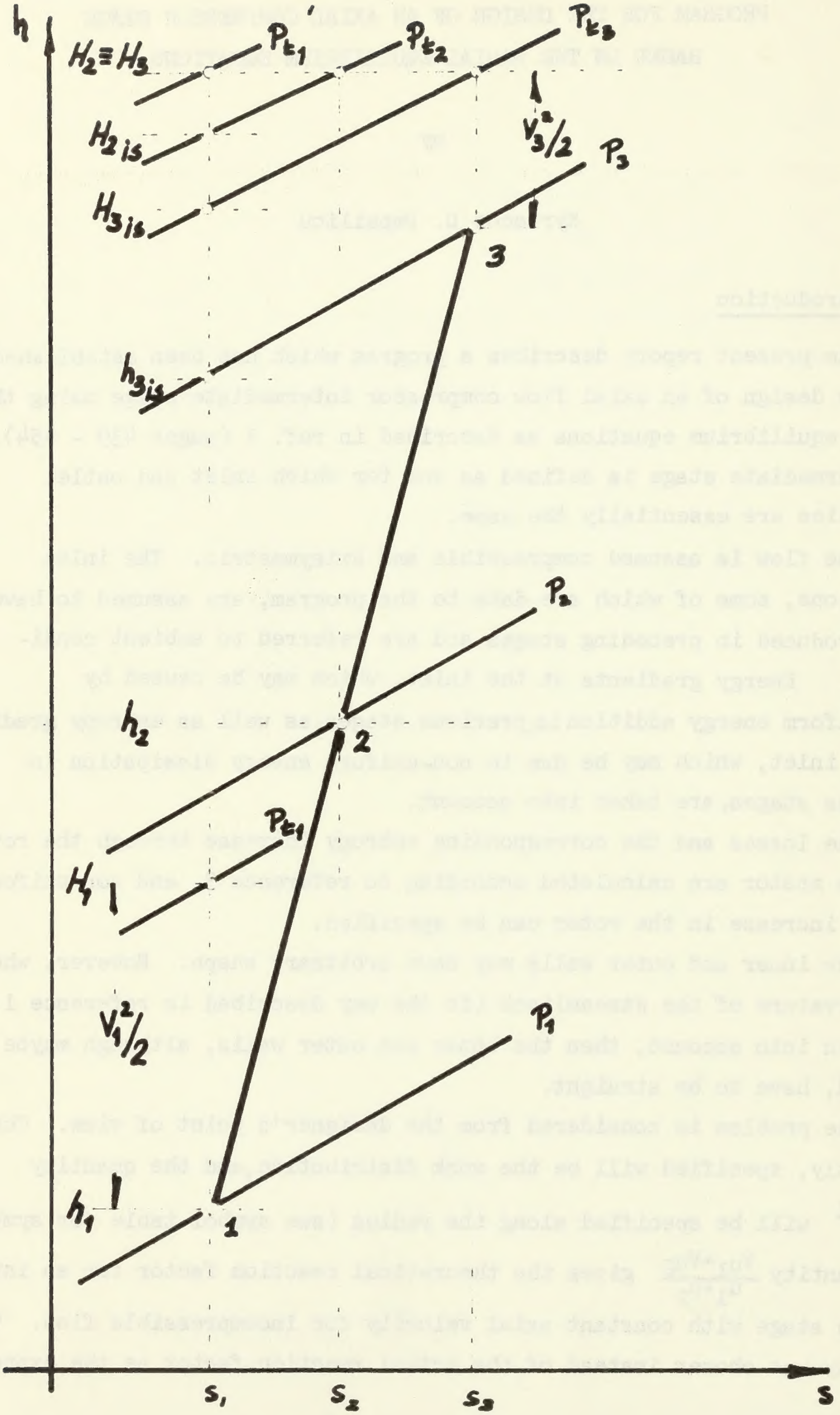

FIG 1. THERMODYNAMIC DIAGRAM

of the actual reaction factor is rather involved in the general case (see Appendix A). The thermodynamic diagram of the process through the stage is given in Figure (1) while the general layout is given in Figure (2).

In the following the theory will first be developed and then the program will be described. Symbols are defined in the symbol table and the FORTRAN Symbol Table.

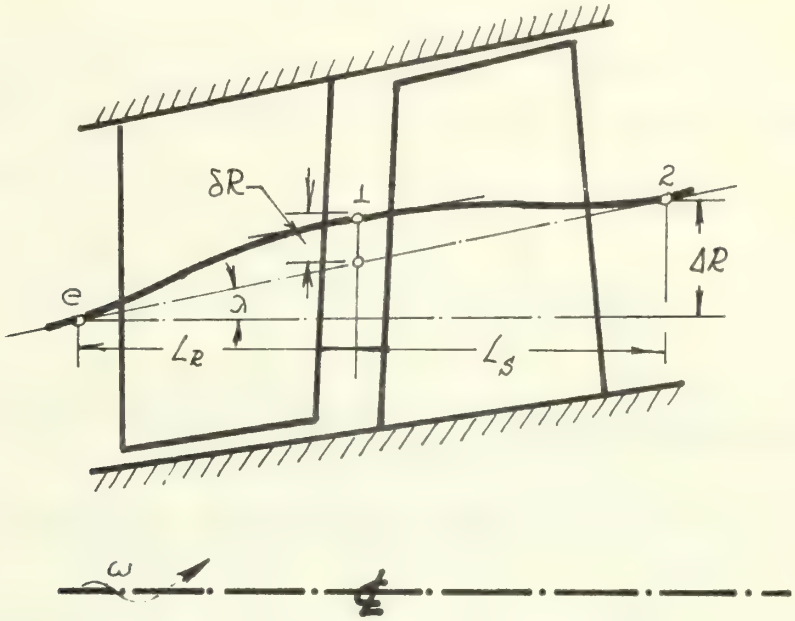

FIG. 2. GENERAL LAYOUT

2. General Equations Used (See Ref. 1)

$$\frac{dV_a^2}{dR} + F V_a^2 + G = 0 \tag{1}$$

where
$$F = - \frac{2}{V_a}\frac{\partial V_r}{\partial z} - \frac{1}{C_p}\frac{1}{\cos^2\lambda}\frac{\partial S}{\partial R} \tag{2}$$

$$G = 2\frac{V_u}{R}\frac{\partial(RV_u)}{\partial R} - 2\frac{\partial H}{\partial R} + \frac{1}{C_p}(2H - V_u^2)\frac{\partial S}{\partial R} \tag{3}$$

with
$$- \frac{2}{V_a}\frac{\partial V_r}{\partial z} = \frac{2K_m}{\cos^3\lambda} = \pm 2K\frac{\delta R}{L^2} \tag{4}$$

The minus sign holds for stations ⓔ and ② and the plus sign for station ①*

---

*Note that there is a discrepancy between the way equation (4) is interpreted here and in ref. 1. However, positive curvature is considered here in accordance with the way equations (1), (2) and (3) have been developed.

where $\tan \lambda_e = \tan \lambda_1 = \tan \lambda_2 = \frac{\Delta R}{2L}$ (5)

$$L = \frac{L_S + L_R}{2} \quad \text{(See Fig. 2)} \tag{6}$$

K takes the values 4 to 6.

The solution of equation (1) is given as follows

$$V_a^2 = \exp\left(-\int_{R_h}^{R} F dR\right)\left[V_{a_h}^2 - \int_{R_h}^{R} G \exp\left(+\int_{R_h}^{R'} F dR'\right) dR\right]$$

$$= V_{a_h}^2 e^{-\int_{R_h}^{R} F dR} - e^{-\int_{R_h}^{R} F dR} \cdot \int_{R_h}^{R} G\, e^{\int_{R_h}^{R'} F dR'} dR \tag{7}$$

3. Dimensional and Non-Dimensional Quantities

The basic quantities used are expressed as follows

Lengths in (ft)

velocities in (ft/s)

angular velocity ω in (rad/s)

enthalpies in (ft^2/s^2) or ($\frac{ft-lb}{slug}$)

entropies in ($\frac{ft - lb}{slug, {}^oR}$) or ($\frac{ft^2}{s^2, {}^oR}$)

the specific heat C_p in ($\frac{ft - lb}{slug, {}^oR}$) or ($\frac{ft^2}{s^2, {}^oR}$)

the density in ($slug/ft^3$)

Consequently F has dimensions (ft^{-1})

G has dimensions (ft/s^2)

Calculations will be formed with non-dimensional quantities. As reference quantities will be used: The angular speed ω, the mean radius R_m, where

$$R_m = \frac{R_{t_1} + R_{h_1}}{2} \tag{7a}$$

the atmospheric pressure, temperature and density. We shall call all non-dimensional quantities starred quantities and denote them with a star.

- Lengths will be non-dimensional over R_m. Consequently

$$R^* = \frac{R}{R_m}$$

$$L^* = \frac{L}{R_m}$$

- Velocities will be non-dimensionalized over ωR_m. Consequently (where $V_{ref} = \omega R_m$)

$$V_a^* = \frac{V_a}{\omega R_m} \quad , \quad W_u^* = \frac{W_u}{\omega R_m} \quad , \quad U^* = \frac{U}{\omega R_m} = R^*$$

- Enthalpies will be non-dimensionalized over $\omega^2 R_m^{\,2}$

$$h^* = \frac{h}{\omega^2 R_m^{\,2}} \quad ; \quad H^* = \frac{H}{\omega^2 R_m^{\,2}}$$

- Entropies will be non-dimensionalized over C_p
- Densities will be non-dimensionalized over the atmospheric density
- Pressures will be non-dimensionalized over the atmospheric pressure

4. Problem Formulation

Using non-dimensional quantities (in the described way), we arrive at the following equations

$$\frac{d(V_a^*)^2}{dR^*} + F^*(V_a^*) + G^* = 0 \qquad (1a)$$

where

$$F^* = -\frac{2}{V_a^*}\frac{\partial V_r^*}{\partial z^*} - \frac{1}{\cos^2\lambda}\frac{\partial(S/C_p)}{\partial R^*} \qquad (2a)$$

$$G^* = 2\,\frac{V_u^*}{R^*}\,\frac{\partial(R^*V_u^*)}{\partial R} - \frac{2\partial H^*}{\partial R^*} + (2H^* - (V_u^*)^2)\,\frac{\partial(S/C_p)}{\partial R^*} \qquad (3a)$$

and

$$\left.\begin{aligned} F^* &= F\,R_m \\ G^* &= G/\omega^2 R_m \end{aligned}\right\} \qquad (8)$$

We shall consider now Figure 3. Considering stations ①, ② and ③

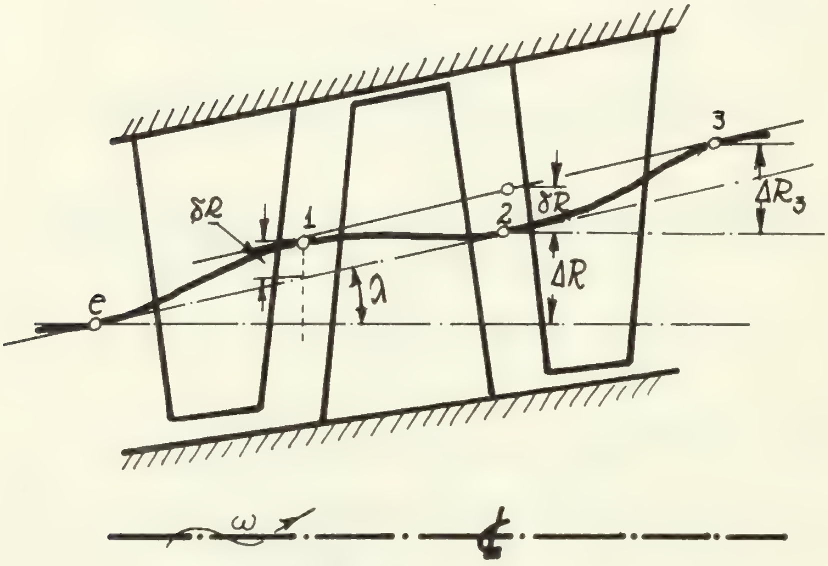

FIGURE 3.

we can see that the angle λ can be found from

$$\tan\lambda = \frac{\Delta R_3}{2L} = \frac{R_3 - R_1}{2L}$$

and still the curvature be calculated using δR at station ② which is now negative measured from the straight line ① - ③, instead from the straight line ⓔ - ②. The curvature expression remains the same if this sign change is taken into account.

5. Necessary Inlet Conditions

Quantities will be specified at equal radial distances at the inlet The distribution of total enthalpy H and the distribution of entropy s must be specified at the inlet. This distribution of entropy and total enthalpy will be considered to have been developed through an adiabatic process (previously existing stages), starting from uniform atmospheric conditions. The atmospheric total pressure and temperature must be also given. Entropies will be measured considering as origin the atmospheric entropy.

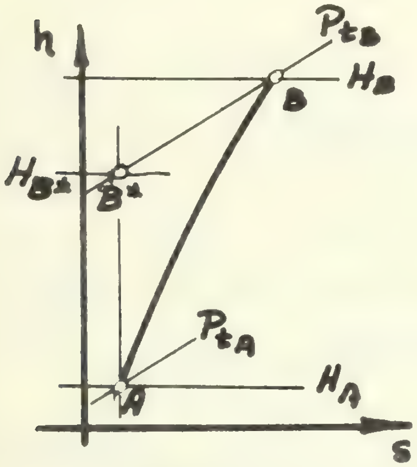

FIG. 4. ADIABATIC COMPRESSION WITH FRICTION.

Considering an adiabatic compression from Ⓐ (atmospheric conditions) to Ⓑ (conditions at the stage inlet) along a stream surface, we have (see Fig. 4 for symbols)

$$S_B - S_{B*} = C_p \ln \left(\frac{H_B}{H_B*}\right) = S_B - S_A = \Delta S$$

or

$$H_B* = H_B \, e^{-\Delta S/C_p}$$

from where H_B* can be calculated. For an isentropic process we have also (from state A to state B*)

$$\frac{P_{tB}*}{P_{tA}} = \frac{P_{tB}}{P_{tA}} = \left(\frac{H_B*}{H_A}\right)^{\gamma/(\gamma-1)} = \left(\frac{H_B \, e^{-\Delta S/C_p}}{C_p \, T_{tA}}\right)^{\frac{\gamma}{(\gamma-1)}}$$

from where the total pressure at the compressor inlet can be calculated. The stagnation density ρ_t is given then as

$$\rho_t = \frac{P_t}{R_g \, T_t} = \frac{C_p \, P_t}{R_g \, H_t}$$

6. General Method of Solution

As can be seen an iterative process is necessary to solve the problem. A first approximation of the streamline position is assumed and on this basis the radial distribution of the axial velocity V_a* is calculated at stations (1), (2) and (3), that satisfies the continuity equation on the whole.

Then, a new approximation of the streamline position is achieved by requiring that the same mass flow passes through individual streamtubes at stations (2) and (3), the radial positions at station (1) remaining the same.

A new V_a*-distribution is then calculated and the iteration continues until the specified number of iterations is achieved. The printed error of each iteration gives us an indication of the convergence of the procedure.

Having established the equations to be solved, a general flow diagram is given in Table I describing the general layout of the program.

7. Detailed Calculations (Following flow diagram of Table I).

Block ①

At stations ①, ② and ③ equidistant radii are considered

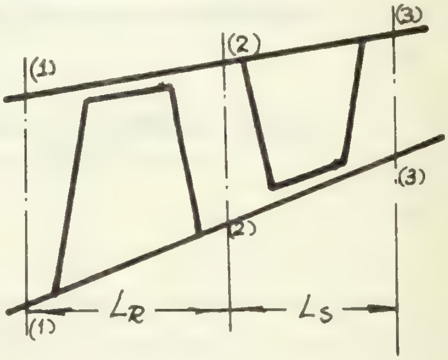

FIG. 5.

Block ②

The total enthalpy increase inside the rotor is

$$\Delta H = \omega \left(R_2 V_{u_2} - R_1 V_{u_1} \right)$$

or $$\Delta H^* = \frac{\Delta H}{\omega^2 R_m^2} = R_2^* V_{u2}^* - R_1^* V_{u1}^*$$

The reaction factor is

$$RF = \frac{V_{u_1} + V_{u_2}}{U_1 + U_2} = \frac{V_{u_1}/\omega R_m + V_{u_2}/\omega R_m}{U_1/\omega R_m + U_2/\omega R_m} = \frac{V_{u_1}{}^* + V_{u_2}{}^*}{R_1{}^* + R_2{}^*}$$

or finally

$$V_{u_1}{}^* = \frac{RF(R_1{}^* + R_2{}^*) - \Delta H^*/R_2{}^*}{1 + R_1{}^*/R_2{}^*} \qquad (9)$$

$$V_{u_2}{}^* = \frac{RF(R_1{}^* + R_2{}^*) + \Delta H^*/R_1{}^*}{1 + R_2{}^*/R_1{}^*} \qquad (10)$$

$$V_{u_3}{}^* = V_{u_1}{}^*$$

Block ③

Calculations are performed without losses in the stage nor curvature effects for the first iteration. Corresponding terms are set here equal to zero.

Block ④

The curvature term is calculated according to equation (4) rewritten here

$$\frac{CRTERM}{Rm} = -\frac{2}{V_a}\frac{\partial V_r}{\partial z} = \pm 2K\frac{\delta R}{L^2} \qquad (11)$$

Note that in the way Vavra describes the curvature in page 453 of ref. (1), there exists an inconsistency in sign with the derived equations of motion. In fact the plus sign belongs to station $z = 0$ of ref. (1) or stations (1) and (3) here, while the minus sign to station (2) here (if δR is taken to be a positive quantity). The expression for the curvature term then becomes

$$CRTERM = -\frac{2}{V_a}\frac{\partial V_r}{\partial z} R_m = \pm 2K\frac{\delta R}{L^2} Rm =$$

$$= \pm 2K \frac{\delta R^*}{\left(\frac{L_S{}^* + L_R{}^*}{2}\right)^2} = \pm K \frac{\frac{R_3{}^* + R_1{}^*}{2} - R_2{}^*}{\left(\frac{L_S{}^* + L_R{}^*}{2}\right)^2} \qquad (12)$$

In this expression δR^* is positive in the way shown in fig. 3 and (+) sign applies to stations (1) and (3) while (-) applies to station (2).

The losses in total pressure are calculated in a subroutine,the theoretical basis of which is given in appendix B. This was decided in order to have the freedom of introducing any loss-correlation we desire.

The subroutine will furnish to us the decrease in total pressure non-dimensionalized over the atmospheric pressure.

The resulting entropy increase will then be calculated as

$$\frac{\Delta S}{C_p} = - \frac{R_g}{C_p} \ln \left(\frac{P_o - \Delta P_o}{P_o} \right)$$

where P_o corresponds to the total pressure level without losses. For the rotor this total pressure is P_{t_1}' (see fig. 1) which is the corresponding total pressure that would result if the addition of enthalpy $H_2 - H_1$ were done isentropically. Then we have

$$\frac{P_{t_1}'}{P_{t_1}} = \left(\frac{H_2}{H_1} \right)^{\frac{\gamma}{\gamma-1}} \quad \text{or} \quad \frac{P_{t_1}'^{*}}{P_{t_1}^{*}} = \left(\frac{H_2^{*}}{H_1^{*}} \right)^{\frac{\gamma}{(\gamma-1)}} \qquad (13)$$

and

$$\frac{S_2 - S_1}{C_p} = - \frac{R_g}{C_p} \ln \left[\frac{P_{t_1}^{*} \left(\frac{H_2^{*}}{H_1^{*}} \right)^{\frac{\gamma}{\gamma-1}} - (\Delta P_o^{*})_R}{P_{t_1}^{*} \left(\frac{H_2^{*}}{H_1^{*}} \right)^{\frac{\gamma}{\gamma-1}}} \right] =$$

$$= - \frac{R_g}{C_p} \ln \left[1 - \frac{\Delta P_{t_1}^{*}}{P_{t_1}^{*}} \left(\frac{H_1^{*}}{H_2^{*}} \right)^{\frac{\gamma}{(\gamma-1)}} \right] = S_2^{*} - S_1^{*} \qquad (14)$$

For the stator P_o comes to be equivalent to P_{t_2} and the increase in entropy from station (2) to station (3) is given as

$$\frac{\Delta S}{C_p} = - \frac{R_g}{C_p} \ln \left(\frac{P_{t_2} - (\Delta P_o)_S}{P_{t_2}} \right)$$

or

$$\frac{S_3 - S_2}{C_p} = S_3^{*} - S_2^{*} = - \frac{R_g}{C_p} \ln \left(1 - \frac{(\Delta P_o^{*})_S}{P_{t_2}^{*}} \right) = S_3^{*} - S_2^{*} \qquad (15)$$

Block ⑤

The subroutine DERIR (see description in ref. (4)) is used to find the derivatives of a function given at discrete points. Thus $\frac{\partial H^*}{\partial R^*}$, $\frac{\partial S^*}{\partial R^*}$ and $\frac{\partial(R^*V_u^*)}{\partial R^*}$ are calculated. Then the functions F* and G* are calculated as given in equations (2a) and (3a).

Block ⑥

The integrals of equation (7) are calculated (FUNC1 and FUNC2) and the distribution of $(V_a^*)^2$ is considered in the following form

$$(V_a^*)^2 = \text{FUNC1} \quad (V_{a_h}^*)^2 + \text{FUNC2}$$

An iteration is initiated using as starting $V_{a_h}^*$ value one which does not make the quantity $(V_a^*)^2$ negative. The iteration scheme is described in ref. 4 (iteration subroutine ITERN).

For each value of $(V_{a_h}^*)$, the (V_a^*) - distribution is calculated for the station under consideration. The iteration process ends when the continuity equation is satisfied.

Block ⑦

The continuity equation is considered in the following way. Consider the actual axial velocity distribution at a section, $V_a^* = V_a^*(R^*)$. Then the corresponding mass flow is

$$Q^*_{real} = \int_{R_h}^{R_t} 2\pi\rho^* V_a^* R^* dR^* \tag{16}$$

Consider now a hypothetical situation where the part of the inviscid flow distribution of V_a^* is extended inside the wall boundary layer regions up to the walls. Then using this distribution we get a mass flow rate Q*, where

$$Q^* = \int_{R_h}^{R_t} 2\pi\rho^* V^*_{a_{inviscid}} R^* dR^*$$

then

$$Q^* > Q^*_{real}$$

and $V^*_{a_{inviscid}}(R^*)$ differ from $V_a^*(R^*)$ only inside the wall boundary layer regions.

We can say now that normally a flow rate Q* would pass through the area given, if it were not for the wall boundary layer presence. Defining a blockage factor K_b as

$$K_b = \frac{Q^*_{real}}{Q^*} \tag{17}$$

then

$$\frac{Q^*_{real}}{K_b} = Q^* = \int_{R_h}^{R_t} 2\pi\rho^* V_a{}^*{}_{inviscid} \; R^*\, dR^* \tag{18}$$

where the mass flow rate has been non-dimensionalized as follows

$$Q^* = \frac{Q}{\rho_{atm}\,\omega R_m{}^3}$$

In the program the inviscid velocity distribution $Va^*_{inviscid}$ is calculated and throughout the whole report this is being referred to as $V_a{}^*$. The mass flow calculated at each station then is Q* and then $K_b\,Q^*$ is compared with Q^*_{real}.

The calculation of the density ρ* needed in the continuity equation is performed as follows: The absolute velocity is calculated as

$$V^* = \sqrt{(V_u{}^*)^2 + (V_a{}^*)^2 + (V_r{}^*)^2}$$

$$= \sqrt{(V_u{}^*)^2 + (V_a{}^*)^2 + (V_a{}^*)^2 \tan^2\lambda} \tag{19}$$

The static temperature is calculated as

$$T = \frac{H^*}{C_p} - \frac{(V^*)^2}{C_p} \quad \omega^2 R_m{}^2 \;({}^oR) \tag{20}$$

The velocity of sound is calculated as

$$a^* = \frac{a}{\omega R_m} = \frac{\sqrt{\gamma\, Rg\, T}}{\omega R_m} \tag{21}$$

The Mach number is calculated as

$$M = \frac{V^*}{a^*} \tag{22}$$

Then the density is:

$$\rho^* = \frac{\rho}{\rho_{atm}} = \frac{C_p\ P_t}{R_g\ H\ \rho_{atm}} \left(1 + \frac{\gamma-1}{2} M^2\right)^{-\frac{1}{(\gamma-1)}}$$

$$= \frac{C_p}{R_g} \frac{P_t{}^*\ P_{atm}}{H^*\ \omega^2\ R_m{}^2\ \rho_{atm}} \left(1 + \frac{\gamma-1}{2}\ M^2\right)^{-\frac{1}{(\gamma-1)}}$$

$$= \frac{P_t{}^*}{H^*}\ H^*_{atm} \left(1 + \frac{\gamma-1}{2} M^2\right)^{\frac{1}{-(\gamma-1)}} \qquad (23)$$

The calculation of the mass flow rate at each radial position is performed with the subroutine SUMAT which uses Simpson's rule for unequal intervals. The subroutine SUMAT makes use of the subroutine INTP0 for interpolation which is described in detail in ref. 2.

Once these calculations are performed the program gives control to the subroutine ITERN which performs the iteration, until convergence has been realized and the continuity equation is satisfied.

Block ⑧

The radial position of the streamlines at station (1) is considered the same throughout the calculation and in this step the radial positions of the streamlines at stations (2) and (3) are found with the condition that the same mass flow is allowed to pass through each streamtube with the newly calculated axial velocity distribution.

Block ⑨

The square root of the sum of the squares of the difference between the old and new position of the streamlines is calculated for stations (2) and (3). This is considered here as an indication of the convergence of the procedure. Additionally in this step all pertinent quantities that have not been calculated up to now are calculated (static and total pressures, relative velocities and mach numbers, angles, etc).

Block ⑩

Once the prescribed number of iterations has been performed, some additional pertinent dimensional and non-dimensional quantities are calculated (a description of the calculation is given in Appendix C), and all the results are printed.

The whole procedure is executed as many times as additional set of data exist.

8. Description of the Use of the Program

This program has been constructed as a complement to ref. 2. An effort was made to take into account entropy and energy gradients (entropy gradients existing at the inlet or introduced through the loss correlations after each row, and energy gradients existing at the inlet or introduced by a non-uniform work distribution in the rotor) and compressibility effects.

The non-dimensionsalization proposed in ref. 2 which does not take these effects into account is rendered thus incomplete and it was decided to carry out the calculation in the non-dimensional form proposed in reference 2 and modified slightly as described already, introducing, however, the data in dimensional form, reflecting thus the Mach number level.

A detailed description of the program has already been given. The meaning of the weight factor has to be explained here. It happens sometimes in complicated cases that the iteration procedure diverges when the calculated corrections for the new streamline position are used in the whole. If, however, a fraction of the corrections is considered and introduced for the next iteration, the iteration procedure may be forced to converge. The weight factor ($0. < W.F. \leq 1.$) introduced as data to the program defines the fraction of the correction to be used for the following iteration loop.

Cases have been already run for no curvature effects and no losses. Then losses were introduced and curvature effects. It was found that to take into account the curvature effects and have an converging iteration process, a value of the weight factors smaller than unity ought to be used.

To facilitate the use of the program a table with a typical input has been prepared and given in Table II. The maximum number of streamlines is taken to be eleven. The listing of the program along with the subroutines in use is given in Table III. The results of the already given typical input are given in Table IV. The explanation of the symbols used along with all the pertinent parameters used in the program are given in the FORTRAN Symbol Table. The output symbols not described in the FORTRAN Symbol Table will be found in the Output Symbol Table. For dimensional quantities the already given dimensions are used. For non-dimensional quantities the already described non-dimensionalization has been done. In the FORTRAN Symbol Table the dimensional variables are given. The non-dimensional ones are denoted in the program with the letter S at the end of the name of the dimensional quantity unless otherwise stated.

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2. Vavra, M. H., Aerodynamic Design of Symmetrical Blading for Three-Stage Axial Flow Compressor Test Rig, NPS-57Va70091A, Naval Postgraduate School, Sept. 1970.
3. Sleinke, Ronald and Crouse, James, Analytical Studies of Aspect Ratio and Curvature Variations for Axial-Flow-Compressor-Inlet Stages under High Loading.
4. Papailiou, K. D., Roels, N., and Schwers, F., Some IBM 1130 Auxiliary Subroutines, Von Karman Institute IN 31 (1969).

TABLE OF FORTRAN SYMBOLS USED IN THE MAIN PROGRAM

Remarks:

(a) If a variable is dimensioned by (11, 3) this means that the variable allows for maximum eleven radial stations and for the three axial positions.

(b) If a variable is dimensioned by (11) this means that the variable allows for maximum eleven radial positions.

(c) Unless otherwise indicated in the symbol table all non-dimensional or starred quantities are indicated by adding an S to the name of the dimensional variable.

FORTRAN SYMBOL	SYMBOL	UNITS	DESCRIPTION
VREF	V_{ref}	ft/s	reference velocity. equals ωR_m
NITER		--	The number of iterations desired before printing the results
CURV	k	--	The constant (usually taking the value 4) appearing in the curvature term
KB(3)	k_B	--	blockage factor array for the three stations
ROT(11,3)	ρ_t	slug/ft^3	total density table
MSFLOW	Q	slug/sec	mass flow rate
MSFLOS	Q^*	--	non-dimensional mass flow rate
DUM(11),		--	Auxiliary variables
RR(11),		--	
RRR(11)		--	
DVUDR(11,3)	$\frac{\partial(R^* V_u^*)}{\partial R^*}$	--	tangential velocity gradient table
LAMDA(11)	λ	rad	angle defined in figure (2)
CRTERM(11)		--	curvature term table
DPTS(11)	ΔP_t^*	--	non-dimensional total pressure loss table for all radial positions at the station considered
DSDRS(11,3)	$\frac{\partial S^*}{\partial R^*}$	--	entropy gradient table
DHDRS(11,3)	$\frac{\partial H^*}{\partial R^*}$	--	total enthalpy gradient

FORTRAN SYMBOL	SYMBOL	UNITS	DESCRIPTION
OMEGA	ω	sec^{-1}	angular velocity of the rotor
PI	π	--	3.141593
RPM	rpm	min^{-1}	revolutions per minute
RM	R_m	ft	mean diameter at station (1)
RH1 RH2 RH3	R_{h1} R_{h2} R_{h3}	ft	hub diameters at stations (1), (2), and (3) respectively
RT1 RT2 RT3	R_{t1} R_{t2} R_{t3}	ft	tip diameters at stations (1), (2), and (3) respectively
	VREF	V_{ref}	reference velocity (ωR_m)
N	n	--	number of radial equidistant positions considered
GAMA	γ	--	isentropic exponent of gas
RG	Rg	$\frac{ft - lb}{slug, {}^oR}$	gas constant
CP	C_p	$\frac{ft - lb}{slug, {}^oR}$	gas specific heat
ROATH	ρ_{atm}	$slug/ft^3$	atmospheric density
PATM	P_{atm}	lb/ft^2	atmospheric pressure
TATM	T_{atm}	${}^oR$	atmospheric temperature
HATM	H_{atm}	$\frac{ft^2}{sec^2}$	atmospheric total enthalpy

FORTRAN SYMBOL	SYMBOL	UNITS	DESCRIPTION
PT(11,3)	P_t	lb/ft^2	total pressure table for all radial positions at the three stations
H(11,3)	H	$\frac{ft^2}{sec^2}$	total enthalpy table for all radial positions at the three stations
S(11,3)	S	$\frac{ft - lb}{slug, {}^oR}$	entropy table (measured from atmospheric conditions)for all radial positions at three stations
DH(11)	ΔH	$\frac{ft^2}{sec^2}$	increase in total enthalpy at all radial positions inside the rotor
TEST1		--	indicator. It indicates the number of passes
R(11,3)	R*,R	-- or ft	the non-dimensionalized radii table for all radial positions at all radial stations
LR	$L_R, L_R{}^*$	ft or --	axial length of the rotor used with dimensions first and without dimensions later
LS	$L_S, L_S{}^*$	ft or --	axial length of the stator used with dimensions first and without dimensions later
VA(11,3)	V_a	ft/sec	axial velocity table
VR(11,3)	V_r	ft/sec	radial velocity table
VU(11,3)	V_u	ft/sec	peripheral velocity table
RF(11)	R.F.	--	reaction factor table for all radial positions
SIGR(11)	σ_R	--	rotor solidity array for all radial positions
SIGS(11)	σ_S	--	stator solidity array for all radial positions
WFACT	--	--	weight factor

FORTRAN SYMBOL	SYMBOL	UNITS	DESCRIPTION
DUM1(11)	--	--	Auxiliary or dummy variables
DUM2(11)	--	--	
DUM3(11)	--	--	
DUM4(11)	--	--	
DER(11)	--	--	
DEB,FIN,	--	--	Variables employed in subroutine ITERN See ref. 3 for explanations
DE,NA1,	--	--	
EPS,F2,NS	--	--	
V(11,3)	V	ft/s	absolute velocity table.
MSFLS(11,3)		--	mass flow rate table passing from each streamtube at each station
SOND(11,3)	a	ft/s	velocity of sound table
TOT(11,3)	T_t	$^{\circ}R$	total temperature table
U(11,3)	U	ft/s	peripheral velocity table
C(11,3)	W	ft/s	relative velocity table
WU	W_u	ft/s	peripheral component of relative velocity table
F(11,3)	F^*	--	function appearing in the radial equilibrium equation
G(11,3)	G^*	--	function appearing in the radial equilibrium equation
FUNC1(11), FUNC2(11)		-- --	function appearing in the solution of the radial equilibrium equation
SOUND(11,3)	a^*	a^*	non-dimensional velocity of sound
T(11,3)	T_s	$^{\circ}R$	static temperature table
MACH(11,3)	M	--	Mach number table

FORTRAN SYMBOL	SYMBOL	UNITS	DESCRIPTION
STDEN(11,3)	$\rho*$	--	non-dimensional static density table
ERROR(3)		--	the mean square root of the differences of the old and new streamline positions indicating the convergence status
DPTR(11)	$(\Delta P_t*)_R$	--	non-dimensional total pressure increase through rotor table
DPTST(11)	$(\Delta P_t*)_{ST}$	--	non-dimensional total pressure increase through stage table
DPSR(11)	ΔP_R*	--	non-dimensional static pressure increase through rotor table
DPSS(11)	ΔP_S*	--	non-dimensional static pressure increase through stator table
DPSST(11)	ΔP_{ST}^*	--	non-dimensional static pressure increase through stage table
TT2IS	$(T_{t2})_{is}$	^oR	isentropic total temperature at station (2)
TS3IS	$(T_3)_{is}$	^oR	isentropic static temperature at station (3)
TT3IS	$(T_{t_3})_{is}$	^oR	isentropic total temperature at station (3)
WS(11,3)	$W*$	--	non-dimensional relative velocity table
MACHR(11,3)	M_R	--	relative Mach number table
P(11,3)	P	lb/ft^2	static pressure table
RO(11,3)	ρ	$slug/ft^3$	static density table

FORTRAN SYMBOL	SYMBOL	UNITS	DESCRIPTION
ETAR(11)	η_R	--	total to total rotor efficiency table
ETAS(11)	η_S	--	static to static stator efficiency table
HSTTT	$(\eta_{ST})_{T-T}$	--	total to total stage efficiency
HSTSS	$(\eta_{ST})_{S-S}$	--	static to static stage efficiency
PTBAR1	$\bar{P}_{t_1}{}^*$	--	non-dimensional mass averaged total pressure at rotor inlet
PSBAR1	$\bar{P}_1{}^*$	--	non-dimensional mass averaged static pressure at rotor inlet
ETRBAR	$\bar{\eta}_R$	--	mass averaged total to total rotor efficiency
DPTRB	$(\overline{\Delta P}_t{}^*)_R$	--	non-dimensional mass averaged total pressure increase through the rotor
HSTTTB	$(\bar{\eta}_{ST})_{T-T}$	--	mass-averaged total to total stage efficiency
HSTTSB	$(\bar{\eta}_{ST})_{T-S}$	--	mass-averaged total to static stage efficiency
PTBAR2	$\bar{P}_{t_2}{}^*$	--	non-dimensional mass-averaged total pressure at rotor exit
PTBAR2	$\bar{P}_2{}^*$	--	non-dimensional mass-averaged static pressure at rotor exit
ETSBAR	$\bar{\eta}_S$	--	mass-averaged static to static stator efficiency
PTBAR3	$\bar{P}_{t_3}{}^*$	--	non-dimensional mass-averaged total pressure at the stator exit
PSBAR3	$\bar{P}_3{}^*$	--	non-dimensional mass-averaged static pressure at the stator exit
WFACT		--	weight factor

Output Symbol table

DF	Diffusion factor
ETA T-T	η_{T-F}
ETA S-S	η_{S-S}

APPENDIX A

THE REACTION FACTOR WITH AXIAL VELOCITY VARIATIONS

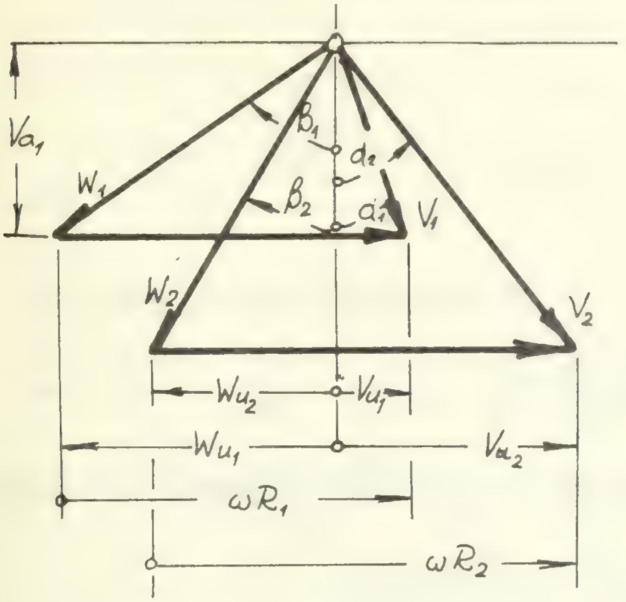


FIG. 1(A) VELOCITY TRIANGLES

FIGURE 1A

$$R_1 \neq R_2$$

$$\Delta H = \omega(R_2 V_{u2} - R_1 V_{u1})$$

$$r^* = \frac{\Delta P_R}{\Delta P_{ST}}$$

Assuming no losses, for incompressible flow

$$\Delta P_R = P_2 - P_1 = (P_{t2})_{REL} - (P_{t1})_{REL} + \rho\left(\frac{U_2^2 - U_1^2}{2} + \frac{W_1^2 - W_2^2}{2}\right)$$

$$= \tfrac{1}{2}\rho(W_1^2 - W_2^2) + \tfrac{1}{2}\rho(U_2^2 - U_1^2)$$

$$= \tfrac{1}{2}\rho(W_{u1}^2 - W_{u2}^2 + V_{a1}^2 - V_{a2}^2) + \tfrac{1}{2}\rho(U_2^2 - U_1^2)$$

$$\Delta P_{ST} = \omega(R_2 V_{u2} - R_1 V_{u1})\,\rho$$

which turns out to give a rather complicated formula for the reaction factor. Consequently, we shall assume that the quantity

$$\frac{V_{u1} + V_{u2}}{U_1 + U_2}$$

is specified along corresponding radii.

APPENDIX B

The correlation described in reference 3 will be used for the calculation of losses (see also reference 4)

The loss coefficient ζ_P is defined for rotors as

$$\zeta_{P_R} = \frac{(\Delta P_o)_R}{P_{t_1} - P_1} = \frac{(\Delta P_o^*)_R}{P_{t_1}^* - P_1^*} \tag{B1}$$

where $\Delta \bar{P}_t$ is the mass averaged total pressure loss, and for stators as

$$\zeta_{P_S} = \frac{(\Delta P_o)_S}{P_{t_2} - P_2} = \frac{(\Delta P_o^*)_S}{P_{t_2}^* - P_2^*} \tag{B2}$$

This definition holds for incompressible flow where the density is assumed constant

The diffusion factor D is given for rotors as

$$D_R = 1 - \frac{W_2}{W_1} + \frac{R_1 W_{u1} - R_2 W_{u2}}{\sigma_R (R_1 + R_2) W_1} \tag{B3}$$

and for stators as

$$D_S = 1 - \frac{V_3}{V_2} + \frac{R_2 V_{u2} - R_3 V_{u3}}{\sigma_S (R_2 + R_3) V_2} \tag{B4}$$

or

$$D_R = 1 - \frac{W_2^*}{W_1^*} + \frac{R_1^* W_{u1}^* - R_2^* W_{u2}^*}{\sigma_R (R_1^* + R_2^*) W_1^*} \tag{B3a}$$

$$D_S = 1 - \frac{V_3^*}{V_2^*} + \frac{R_2^* V_{u2}^* - R_3^* V_{u3}^*}{\sigma_S (R_2^* + R_3^*) V_2^*} \tag{B3b}$$

then

$$\zeta_{P_R} = \frac{2\sigma_R}{\cos \beta_2} \left[0.004 + 0.0639 \, (D_R + 0.1)^{2.91} + 0.228 D_R^{2.02} \, [1 - \lambda_R]^{3.77} \right] \tag{B5}$$

where

$$\lambda_R = \frac{R_{2_t} - R_2}{R_{2_t} - R_{2_h}} = \frac{R_{2_t}^* - R_2^*}{R_{2_t}^* - R_{2_h}^*} \tag{B6}$$

For angles $\beta_2 \geqq 45^\circ$, see Fig. 1A, a correction is offered, where instead of ζ_{P_R} the loss coefficient $(\zeta_{P_R})_{COR}$ is considered, where

$$(\zeta_{P_R})_{COR} = \zeta_{P_R} \cos \beta_2 \sqrt{2} \left[1 - \frac{\pi}{4} + \frac{\pi \beta_2}{180}\right] \tag{B7}$$

For stators

$$\zeta_{P_S} = \frac{2\sigma_S}{\cos\alpha_3} \left[0.004 + 0.0639 (D_S + 0.1)^{2.91} + 0.057 D_S^{2.02} [1 - \lambda_S]^{3.77}\right] \tag{B8}$$

where no correction is offered for $\alpha_3 > 45^\circ$.

The shock losses are calculated as follows:

The amount of supersonic turning is

$$\Delta\nu = \frac{0.625}{\sigma_R} (\beta_1 - \beta_2) \quad \text{for the rotor} \tag{B9}$$

$$= \frac{0.625}{\sigma_S} (\alpha_2 - \alpha_3) \quad \text{for the stator} \tag{B10}$$

The peak suction surface Mach number is then obtained from

$$(M_{S_u}) = 1.095 + 0.03395\, \Delta\nu + 1.086 (M_{R_1} - 1.00)^{1.372} \tag{B11}$$

for a rotor

$$(M_{S_u}) = 1.095 + 0.03395\, \Delta\nu + 1.086 (M_2 - 1.00)^{1.372} \tag{B12}$$

for a stator

The shock losses are then calculated on the basis of the mean Mach number

$$M = \frac{M_{R_1} + M_{S_u}}{2} \quad \text{for a rotor} \tag{B13}$$

$$M = \frac{M_2 + M_{S_u}}{2} \quad \text{for a stator} \tag{B14}$$

as

$$\zeta_{SH} = \frac{1 - \left[\frac{(\gamma+1)M^2}{(\gamma-1)M^2+2}\right]^{\gamma/(\gamma-1)} \left[\frac{\gamma+1}{2\gamma M^2-(\gamma-1)}\right]^{1/(\gamma-1)}}{1 - \left[1+\frac{\gamma-1}{2}M^2\right]^{-\gamma/(\gamma-1)}} \qquad \text{(B15)}$$

where the final loss coefficient is obtained as

$$\zeta = \zeta_P + \zeta_{SH}$$

If the inlet Mach number is smaller than unity, the Mach number M_{Su} is calculated by taking the inlet Mach number M_{R_1} or M_2 to be unity. The mean Mach number M then is calculated using the actual inlet Mach number M_{R_1} or M_2. If $M < 1$ no shock losses are assumed to exist. If $M > 1$. then the shock losses are calculated using equation (B15) and $M = 1$. As pointed out earlier, this procedure is adopted only if the inlet Mach numbers are smaller than unity.

APPENDIX C

The following additional calculations are performed in the program.

(a) The total pressure increase is

$$\Delta P^*_{t_R} = P^*_{t_2} - P^*_{t_1} \qquad \text{for the rotor} \qquad (C1)$$

$$\Delta P^*_{t_{ST}} = P^*_{t_3} - P^*_{t_1} \qquad \text{for the stage} \qquad (C2)$$

(b) The static pressure increase is

$$\Delta P^*_R = P^*_2 - P^*_1 \qquad \text{for the rotor} \qquad (C3)$$

$$\Delta P^*_S = P^*_3 - P^*_2 \qquad \text{for the stator} \qquad (C4)$$

$$\Delta P^*_{ST} = P^*_3 - P^*_1 \qquad \text{for the stage} \qquad (C5)$$

(c) The efficiency is calculated as follows

$$\eta_R = \frac{Cp(T_{t_{2_{is}}} - T_{t_1})}{\Delta H} \qquad \text{total to total efficiency for the rotor} \qquad (C6)$$

$$\eta_S = \frac{T_{3_{is}} - T_2}{T_3 - T_2} \qquad \text{static to static efficiency for the stator} \qquad (C7)$$

$$(\eta_{ST})_{T-T} = \frac{Cp(T_{t_{3_{is}}} - T_{t_1})}{\Delta H} \qquad \text{total to total efficiency for the stage} \qquad (C8)$$

$$(\eta_{ST})_{S-S} = \frac{(T_{3_{is}} - T_1)}{T_3 - T_1} \qquad \text{static to static efficiency for the stage} \qquad (C9)$$

The calculation of the temperatures is being done as follows

$$T_{t_{2_{is}}} = T_{t_2} e^{-(S_2-S_1)/Cp} = T_{t_2} e^{-(S^*_2-S^*_1)} \qquad (C10)$$

$$T_{3_{is}} = T_3 \, e^{-(S_3-S_2)/Cp} = T_3 \, e^{-(S_3^*-S_2^*)} \tag{C11}$$

$$T_{t_{3_{is}}} = T_{t_3} \, e^{-(S_3-S_1)/Cp} = T_{t_3} \, e^{-(S_3^*-S_1^*)} \tag{C12}$$

(d) Mass averaged quantities are calculated. Assuming that we want to calculate the mass averaged value of the quantity Y, then

$$\bar{Y} = \frac{\int_{R_{hub}}^{R_{tip}} 2\pi\rho R \; Va \; Y \; dR}{Q} = \frac{\int_{R^*_{hub}}^{R^*_{tip}} 2\pi\rho^* R^* Va^* \; Y dR^*}{Q^*_{real}/K_b} \tag{C13}$$

or

$$\bar{Y}^* = \frac{2\pi K_b}{Q^*_{real}} \int_{R^*_{hub}}^{R^*_{tip}} \rho^* R^* Va^* \; Y^* \; dR^* \tag{C13a}$$

SYMBOLS

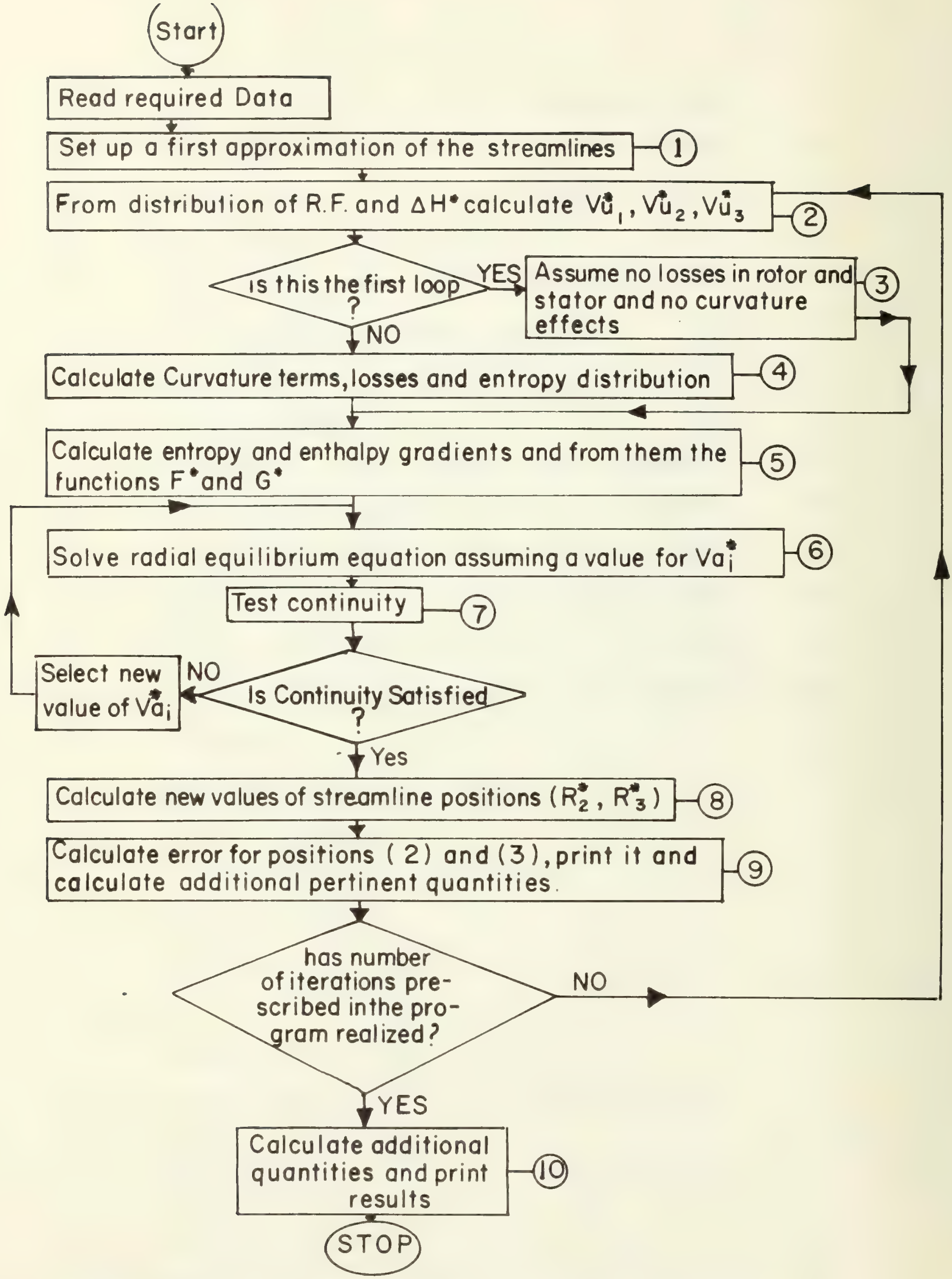
V	absolute velocity
W	relative velocity
U	peripheral velocity
H	total enthalpy
h	static enthalpy
P_t	total pressure
P	static pressure
S	entropy
R	radial distance from compressor axis
ω	angular velocity
L	axial length (see Fig. 2)
λ	angle between axial direction and streamline direction at stations (1), (2), and (3).
$\delta R, \Delta R$	radial distances defined in Fig 2.
F, G	functions defined in equations (1), (2), and (3)
C_p	specific heat at constant pressure
z	axial distance
K	constant used for the evaluation of curvature effects (see equation (4)).
ρ	static density
ρ_t	stagnation density
α	absolute angle measured from the axial direction
β	relative angle measured from the axial direction
R_g	gas constant
γ	ratio of the specific heats at constant pressure and constant volume

T	static temperature
T_t	total temperature
RF	reaction factor
ΔH	total enthalpy increase in the rotor
ΔP_o	loss in total pressure
K_b	wall boundary layer blockage factor
Q	mass flow rate
a	velocity of sound
M	Mach number
ΔP	static pressure increase
ΔP_t	total pressure increase
D	diffusion factor
σ	solidity (chord to pitch ratio)
λ_R, λ_S	non-dimensional quantities defined in equation B6
η	efficiency
ζ_p	profile loss coefficient
ζ_{sh}	shock loss coefficient
$\Delta\nu$	amount of supersonic turning
M	average mach number
ζ	total loss coefficient

Subscripts

1	station ahead of the rotor
2	station behind the rotor and ahead of the stator
3	station behind the stator
a	axial direction
u	peripheral direction

r	radial direction
is	isentropic
e	entrance (see Fig. 2)
R	rotor
s	stator
h	hub
t	tip
m	mean
atm	atmospheric
ref	reference
st	stage
su	suction surface
cor	corrected
rel	relative



NOTE: This procedure is repeated as many times as necessary to cover all cases introduced as data along with the program

GENERAL FLOW DIAGRAM OF THE PROGRAM

TABLE II

NCASE	
01	
N	NITER
009	020

RH1	RH2	RH3	RT1
+0.90000000E-00	+0.90000000E-00	+0.90000000E-00	+0.15000000E+01
RT2	RT3	LS	LR
+0.15000000E+01	+0.15000000E+01	+0.20800000E-00	+0.20800000E-00
RF1	RF2	RF3	RF4
+0.50000000E-00	+0.50000000E-00	+0.50000000E-00	+0.50000000E-00
RF5	RF6	RF7	RF8
+0.50000000E-00	+0.50000000E-00	+0.50000000E-00	+0.50000000E-00
RF9			
+0.50000000E-00			
DH1	DH2	DH3	DH4
+0.30295760E+05	+0.30295760E+05	+0.30295760E+05	+0.30295760E+05
DH5	DH6	DH7	DH8
+0.30295760E+05	+0.30295760E+05	+0.30295760E+05	+0.30295760E+05
DH9			
+0.30295760E+05			

TABLE II (CONTINUED)

S1	S2	S3	S4
+0.	+0.	+0.	+0.
S5	S6	S7	S8
+0.	+0.	+0.	+0.
S9			
+0.			
CP	RPM	PATM	TATM
+0.60047000E+04	+0.22900000E+04	+0.21152300E+04	+0.52000000E+03
RG	CURV		
+0.17156300E+04	+0.40000000E+01		
H1	H2	H3	H4
+0.31224440E+07	+0.31224440E+07	+0.31224440E+07	+0.31224440E+07
H5	H6	H7	H8
+0.31224440E+07	+0.31224440E+07	+0.31224440E+07	+0.31224440E+07
H9			
+0.31224440E+07			
KB1	KB2	KB3	MSFLOW
+0.10000000E+01	+0.96500000E-00	+0.94000000E-00	+0.24516140E+01
SIGR1	SIGR2	SIGR3	SIGR4
+0.10610000E+01	+0.10200000E+01	+0.98500000E-00	+0.95500000E-00

TABLE II (CONTINUED)

SIGR5	SIGR6	SIGR7	SIGR8
+0.92800000E-00	+0.90500000E-00	+0.88400000E-00	+0.86500000E-00
SIGR9			
+0.84900000E-00			
SIGS1	SIGS2	SIGS3	SIGS4
+0.12260000E+01	+0.11100000+01	+0.10100000E+01	+0.92400000E-00
SIGS5	SIGS6	SIGS7	SIGS8
+0.84900000E-00	+0.78200000E-00	+0.72300000E-00	+0.67000000E-00
SIGS9			
+0.62200000E-00			
WFACT			
+0.10000000E-00			

```
FORTRAN IV G LEVEL  18                MAIN              DATE = 71251         17/06/32                    PAGE 0001

            REAL KB(3),LR,LS,MSFLOW,MSFLOS,MSFLS(11,3),LAMDA(11),MACH(11,3)
           1,MACHR(11,3)
            INTEGER TEST1
            DIMENSIONRF(11),DH(11),S(11,3),H(11,3),PT(11,3),ROT(11,3),
           1SS(11,3),HS(11,3),DHS(11),                ROTS(11,3),DR(3),VUS(11,3),DUM
           2(11),RR(11),DER(11),DSDRS(11,3),DHDRS(11,3),DVUDR(11,3),DUM1(11),C
           3RTERM(11),            F(11,3),G(11,3),FUNC1(11,3),FUNC2(11,3),VAS(11,
           43),VRS(11,3),VS(11,3),T(11,3),SOUND(11,3),DUM2(11),   STDEN(11,3)
           5,RRR(11,3),Z(3),W(3),ERROR(2)   ,DUM3(11),DUM4(11),SIGS(11)
            DIMENSION SIGR(11),  VU(11,3),VA(11,3),VR(11,3),V(11,3),SOND(11,3)
           1,TOT(11,3),U(11,3),WUS(11,3),ALFA(11,3),BETA(11,3),WS(11,3)
           2       ,WU(11,3),C(11,3),               P(11,3),TS(11,3),RO(11,3)
            DIMENSION DPTR(11),DPTST(11),DPSR(11),DPSS(11),DPSST(11),ETAR(11)
           1,ETAS(11),HSTTT(11),HSTSS(11)
            COMMON R(11,3),DFAC(11,2),PTS(11,3),PS(11,3),DPTS(11,2)
C***
C***        DATA READOUT
C***
            READ(5,1100)NCASE
      1100  FORMAT(I2)
            DO 950 NNUM=1, NCASE
            READ(5,101)N,NITER
            READ(5,100)RH1,RH2,RH3,RT1,RT2,RT3,LS,LR
            READ(5,100)(RF(I),I=1,N)
            READ(5,100)(DH(I),I=1,N)
            READ(5,100)(S(I,1),I=1,N)
            READ(5,100)CP,RPM,    PATM,TATM,RG,CURV
            READ(5,100)(H(I,1),I=1,N)
            READ(5,100)(KB(I),I=1,3),MSFLOW
            READ(5,100)(SIGR(I),I=1,N)
            READ(5,100)(SIGS(I),I=1,N)
            READ(5,100)WFACT
C***
C***        SOME PRELIMINARY CALCULATIONS   OF QUANTITIES USED THROUGHOUT
C***        THE PROGRAM
C***
            PI=3.141593
            OMEGA=PI*RPM/30.
            RM=(RH1+RT1)/2.
            VREF=OMEGA*RM
            AN=N
            AN1=N-1
            GAMA=1./(1.-RG/CP)
            ROATM=PATM/(RG*TATM)
            HATM=CP*TATM
            DO 200 I=1,N
            PT(I,1)=PATM*(H(I,1)/EXP( S(I,1)/CP)/HATM)**(GAMA/(GAMA-1.))
       200  ROT(I,1)=PT(I,1)*CP/(RG*H(I,1))
            N1=N-1
            DO 212 I=1,N
            H(I,2)=H(I,1)+DH(I)
       212  H(I,3)=H(I,2)
            MSFLOS=MSFLOW/(ROATM*OMEGA*RM**3)
            HATMS=HATM/VREF**2
C***
C***        NON DIMENSIONALIZED QUANTITIES
C***
            R(1,1)=RH1/RM
            R(N,1)=RT1/RM
            R(1,2)=RH2/RM
            R(N,2)=RT2/RM
            R(1,3)=RH3/RM
            R(N,3)=RT3/RM
            DO 201 I=1,N
            SS(I,1)=S(I,1)/CP
            HS(I,1)=H(I,1)/VREF**2
            DHS(I)=DH(I)/VREF**2
            PTS(I,1)=PT(I,1)/PATM
       201  ROTS(I,1)=ROT(I,1)/ROATM
            LR=LR/RM
            LS=LS/RM
            DO 213 I=1,N
            HS(I,2)=HS(I,1)+DHS(I)
```

TABLE III

```
  213 HS(I,3)=HS(I,2)
C***
C***  FIRST APPROXIMATION OF THE STREAMLINE POSITION (STEP 1 )
C***
      DO 203 I=1,3
  203 DR(I)=(R(N,I)-R(1,I))/AN1
      DO 202 J=1,3
      DO 202 I=2,N1
  202 R(I,J)=R(I-1,J)+DR(J)
C***
C***  PRINTOUT OF INPUT DATA
C***
      WRITE(6,121)
  121 FORMAT(1H1,1X'INITIAL DATA'/1X,'------------'//,7X,'RH1',14X,'RH2
     1',12X,'RH3',12X,'RT1',13X,'RT2',13X,'RT3')
      WRITE(6,122)RH1,RH2,RH3,RT1,RT2,RT3
  122 FORMAT(6(1X,E15.8),/)
      WRITE(6,123)LS,LR,RPM,RG,CURV,GAMA
  123 FORMAT(7X,'LS',15X,'LR',14X,'RPM',12X,'RG',13X,'CURV',13X,'GAMA',
     1/,6(1X,E15.8)/)
      WRITE(6,124)KB(1),KB(2),KB(3),PATM,TATM,ROATM,MSFLOW
  124 FORMAT(7X,'KB1',14X,'KB2',12X,'KB3',13X,'PATM',13X,'TATM',11X,'RO
     1ATM'/,6(1X,E15.8),//,3X,'MASS FLOW'/,1X,E15 .8,//,7X,'S1',15X,'RF
     2',15X,'DH',15X,'H1'/)
      WRITE(6,125)(S(I,1),RF(I),DH(I),H(I,1),I=1,N)
  125 FORMAT(4(1X,E15.8))
      WRITE(6,900)
  900 FORMAT(1H1)
      WRITE(6,126)
  126 FORMAT(1X,'FINAL RESULTS'/,1X,'---------------',//,1X,'ITERATION',1
     16X,'ERROR 1',8X,'ERROR 2',/)
      TEST1=1
      DO 280 IPASS=1,NITER
C***
C***  CALCULATION OF VU1*, VU2*, VU3* ( STEP 2 )
C***
  205 DO 204 I=1,N
      VUS(I,1)=(RF(I)*(R(I,1)+R(I,2))-DHS(I)/R(I,2))/(1.+R(I,1)/R(I,2))
      VUS(I,2)=(RF(I)*(R(I,1)+R(I,2))+DHS(I)/R(I,1))/(1.+R(I,2)/R(I,1))
  204 VUS(I,3)=VUS(I,1)
C***
C***  CALCULATION OF CURVATURE TERM AND ROTOR AND STATOR LOSSES (STEP 4)
C***
      DO 232 J=1,3
      DO 233 I=1,N
      DUM(I)=VUS(I,J)*R(I,J)
  233 RR(I)=R(I,J)
      CALL DERIR(N,RR,DUM,DER)
      DO 234 I=1,N
  234 DVUDR(I,J)=DER(I)
  232 CONTINUE
      DO 208 I=1,N
  208 LAMDA(I)=ATAN((R(I,3)-R(I,1))/(LR+LS))
      IF(TEST1)206,206,207
C***  TEST1 POSITIVE MEANS FIRST  ITERATION LOOP
  206 DO 215 I=1,N
  215 CRTERM(I)=CURV*((R(I,3)+R(I,1))/2.-R(I,2))  /((LR+LS)/2.)**2*2.
      GO TO 216
  207 DO 217 I=1,N
  217 CRTERM(I)=0.
  216 IF(TEST1)218, 218, 219
  218 DO 631 I=1,N
      DUM(I)=WS(I,1)
      DUM1(I)=WS(I,2)
      DUM2(I)=WUS(I,1)
      DUM3(I)=WUS(I,2)
      DUM4(I)=BETA(I,1)
      RR(I)=BETA(I,2)
  631 DER(I)=MACHR(I,1)
      CALL LOSTP( -1   ,DUM,DUM1,DUM2,DUM3,DUM4,RR,DER,SIGR,GAMA,N)
      GO TO 220
  219 DO 221 I=1,N
  221 DPTS(I,1)=0.
```

TABLE III (CONT.)

```
0110            220 DO 209 I=1,N
0111                DD=DPTS(I,1)
0112                SS(I,2)=SS(I,1)-RG/CP*ALOG(1.-DD      /PTS(I,1)*(HS(I,1)/HS(I,2))*
               1*(GAMA/(GAMA-1.)))
0113            209 PTS(I,2)=PTS(I,1)*(HS(I,2)/HS(I,1))**(GAMA/(GAMA-1.))-DD
0114                IF(TEST1)721,721,222
0115            721 DO 632 I=1,N
0116                DUM(I)=VS(I,2)
0117                DUM1(I)=VS(I,3)
0118                DUM2(I)=VUS(I,2)
0119                DUM3(I)=VUS(I,3)
0120                DUM4(I)=ALFA(I,2)
0121                RR(I)=ALFA(I,3)
0122            632 DER(I)=MACH(I,2)
0123                CALL LOSTP(  2  ,DUM,DUM1,DUM2,DUM3,DUM4,RR,DER,SIGS,GAMA,N)
0124                GO TO 223
0125            222 DO 224 I=1,N
0126            224 DPTS(I,2)=0.
0127            223 DO 210 I=1,N
0128                DD=DPTS(I,2)
0129                SS(I,3)=SS(I,2)-RG/CP*ALOG((PTS(I,2)-  DD   )/PTS(I,2))
0130            210 PTS(I,3)=PTS(I,2)-DD
              C***
              C***  CALCULATION OF ENTROPY AND ENERGY GRADIENTS.CALCULATION OF FUNCTI-
              C***  ONS F* AND G* (STEP 5).
              C***
0131                TEST1=-1
0132                DO 225 J=1,3
0133                DO 226 I=1,N
0134                DUM(I)=SS(I,J)
0135            226 RR(I)=R(I,J)
0136                CALL DERIR(N,RR,DUM,DER)
0137                DO 227 I=1,N
0138            227 DSDRS(I,J)=DER(I)
0139                DO 228 I=1,N
0140            228 DUM(I)=HS(I,J)
0141                CALL DERIR(N,RR,DUM,DER)
0142                DO 229 I=1,N
0143            229 DHDRS(I,J)=DER(I)
0144            225 CONTINUE
0145                DO 230 J=1,3
0146                DO 231 I=1,N
0147                F(I,J)=CRTERM(I)-1./COS(LAMDA(I))**2*DSDRS(I,J)
0148                G(I,J)=2.*VUS(I,J)/R(I,J)*DVUDR(I,J)-2.*DHDRS(I,J)+(2.*HS(I,J)-VU
               1S(I,J)**2)*DSDRS(I,J)
0149            231 CRTERM(I)=-CRTERM(I)
0150            230 CONTINUE
              C***
              C***  CALCULATION OF THE INTEGRALS INVOLVED IN THE CALCULATION OF THE
              C***  AXIAL VELOCITY DISTRIBUTION (STEP 6).
0151                DO 734 J=1,3
0152                DO 732 I=1,N
0153                DUM(I)=F(I,J)
0154            732 RR(I)=R(I,J)
0155                CALL SUMAT(N,DUM,RR,DUM1)
0156                DO 733 I=1,N
0157                FUNC1(I,J)=1./EXP(DUM1(I))
0158            733 DUM(I)=G(I,J)*EXP(DUM1(I))
0159                CALL SUMAT(N,DUM,RR,DUM1)
0160                DO 235 I=1,N
0161            235 FUNC2(I,J)=-FUNC1(I,J)*DUM1(I)
0162            734 CONTINUE
              C***
              C***  START THE ITERATION FOR THE CALCULATION OF THE AXIAL VEL. DISTRIB.
              C***  (STEP 6).
              C***
0163                DO 237 J=1,3
0164                DO 260 I=1,N
0165            260 DUM(I)= FUNC2(I,J)/FUNC1(I,J)
0166                A=AMIN1(DUM(1),DUM(2),DUM(3),DUM(4),DUM(5),DUM(6),DUM(7),DUM(8),
               1DUM(9))
0167                IF(A)266,267,267
0168            266 DEB=1.01*SQRT(ABS(A))
```

TABLE III (CONT.)

```
      GOTO 268
  267 DEB=0.
  268 FIN=10.
      DE=.1
      NA1=0
      EPS=.0001
  305 CALL ITEPN(DEB,FIN,DE,EPS,NA1,DEP,X1,X2,X3,F1,F2,NS,NN)
      IF(NS)301,302,303
  301  WRITE(6,1006)
      STOP
  302 DO 238 I=1,N
      VAS(I,J)=SQRT(FUNC1(I,J)*X2**2+FUNC2(I,J))
C***
C***  CONTINUITY CONSIDERATIONS (STEP 7).
C***
      VRS(I,J)=VAS(I,J)*TAN(LAMDA(I))
      VS(I,J)=SQRT(VUS(I,J)**2+VAS(I,J)**2+VRS(I,J)**2)
      T (I,J)=(HS(I,J)-VS(I,J)**2/2.)*VREF**2/CP
      SOUND(I,J)=SQRT(GAMA*RG*T (I,J))/VREF
      MACH(I,J)=VS(I,J)/SOUND(I,J)
      STDEN(I,J)=PTS(I,J)*HATMS/HS(I,J)*(1.+(GAMA-1.)/2.*MACH(I,J)**2)**
     1( 1. /(1.-GAMA))
      DUM(I)=2.*PI*STDEN(I,J)*VAS(I,J)*R(I,J)
  238 RR(I)=R(I,J)
      CALL SUMAT(N,DUM,RR,DUM1)
      F2=DUM1(N)*KB(J)-MSFLOS
      GO TO 305
  303 DO 245 I=1,N
  245 MSFLS(I,J)=DUM1(I)
  237 CONTINUE
C***
C*** CALCULATION OF THE NEW STREAMLINE POSITION (STEP 8).
C***
      DO 272 M=2,3
      I=-1
  274 I=I+1
      DO 271 J=1,3
      J1=I+J
      Z(J)=MSFLS(J1,M)
  271 W(J)=R(J1,M)
      J2=I+2
      SFLS=MSFLS(J2,1)*KB(1)/KB(M)
      CALL INTPO(3, SFLS       ,Z,W)
      RRR(J2,M)=W(1)
      IF(I-N+3)274,275,275
  275 CONTINUE
  272 CONTINUE
      DO 273 J=2,3
      DO 277 I=2,N1
  277 RR(I)=R(I,J)-RRR(I,J)
C***
C*** CALCULATION OF THE ERROR (STEP 9).
C***
      B=0.
      DO 276 I=2,N1
  276 B=B+(RR(I))**2
      ERROR(J-1)=SQRT(B)
      DO 281 I=2,N1
  281 R(I,J)=  R(I,J) -WFACT*RR(I)
  273 CONTINUE
      DO 279 J=2,3
      DO 279 I=1,N
  279 ROTS(I,J)=PTS(I,J)*CP/(RG*H(I,J))*PATM/ROATM
C***
C***  SOME ADDITIONAL CALCULATIONS (STEP 9).
C***
      DO 381 J=1,3
      DO 382 I=1,N
      S(I,J)=SS(I,J)*CP
      ROT(I,J)=ROTS(I,J)*ROATM
      VU(I,J)=VUS(I,J)*VREF
      VA(I,J)=VAS(I,J)*VREF
      VR(I,J)=VRS(I,J)*VREF
```

TABLE III (CONT.)

```
 0229                V(I,J)=VS(I,J)*VREF
 0230                SOND(I,J)=SOUND(I,J)*VREF
 0231                TOT(I,J)=H(I,J)/CP
 0232                U(I,J)=R(I,J)*VREF
 0233                WLS(I,J)=R(I,J)-VUS(I,J)
 0234                ALFA(I,J)=57.29578*ATAN(VUS(I,J)/VAS(I,J))
 0235                BETA(I,J)=57.29578*ATAN(WUS(I,J)/VAS(I,J))
 0236                WS(I,J)=SQRT(VRS(I,J)**2+VAS(I,J)**2+WUS(I,J)**2)
 0237                MACHR(I,J)=WS(I,J)/SOUND(I,J)
 0238                WU(I,J)=WUS(I,J)*VREF
 0239                C(I,J)=WS(I,J)*VREF
 0240                PS(I,J)=PTS(I,J)/(1+(GAMA-1.)/2.*MACH(I,J)**2)**(GAMA/(GAMA-1.))
 0241                TS(I,J)=T(I,J)/TATM
 0242                RO(I,J)=STDEN(I,J)*ROATM
 0243                PT(I,J)=PTS(I,J)*PATM
 0244            382 P(I,J)=PS(I,J)*PATM
 0245            381 CONTINUE
 0246                WRITE(6,127)IPASS,ERROR(1),ERROR(2)
 0247            127 FORMAT(6X,I2,11X,2(1X,E15.8))
 0248            280 CONTINUE
               C***
               C***  CALCULATION OF THE INCREASE IN PRESSURE THROUGH ROTOR STATOR AND
               C***  STAGE(STEP 10).
               C***
 0249                DO 917 I=1,N
 0250                DPTR(I)=PTS(I,2)-PTS(I,1)
 0251                DPTST(I)=PTS(I,3)-PTS(I,2)
 0252                DPSR(I)=PS(I,2)-PS(I,1)
 0253                DPSS(I)=PS(I,3)-PS(I,2)
 0254                DPSST(I)=PS(I,3)-PS(I,1)
               C***
               C***  CALCULATION OF THE EFFICIENCIES (STEP 10).
               C***
 0255                TT2IS=TOT(I,2)/EXP(SS(I,2)-SS(I,1))
 0256                ETAR(I)=(TT2IS-TOT(I,1))/(TOT(I,2)-TOT(I,1))
 0257                TS3IS=TS(I,3)/EXP(SS(I,3)-SS(I,2))
 0258                ETAS(I)=(TS3IS-TS(I,2))/(TS(I,3)-TS(I,2))
 0259                TT3IS=TOT(I,3)/EXP(SS(I,3)-SS(I,1))
 0260                HSTTT(I)=(TT3IS-TOT(I,1))/(TOT(I,3)-TOT(I,1))
 0261            917 HSTSS(I)=(TS3IS*TATM-T  (I,1))/(T  (I,3)-T  (I,1))
               C***
               C***  CALCULATION OF THE MASS AVERAGED QUANTITIES(STEP 10).
               C***
 0262                DO 921 I=1,N
 0263                DUM(I)=R(I,1)
 0264                DUM1(I)=VAS(I,1)
 0265                DUM2(I)=PTS(I,1)
 0266            921 DUM3(I)=STDEN(I,1)
 0267                CALL AVER(DUM,DUM1,DUM2,DUM3,MSFLOS,KB(1),PTBAR1,N)
 0268                DO 922 I=1,N
 0269            922 DUM2(I)=PS(I,1)
 0270                CALL AVER(DUM,DUM1,DUM2,DUM3,MSFLOS,KB(1),PSBAR1,N)
 0271                DO 923 I=1,N
 0272            923 DUM2(I)=ETAR(I)
 0273                CALL AVER(DUM,DUM1,DUM2,DUM3,MSFLOS,KB(1),ETRBAR,N)
 0274                DO 924 I=1,N
 0275            924 DUM2(I)=DPTR(I)
 0276                CALL AVER(DUM,DUM1,DUM2,DUM3,MSFLOS,KB(1),DPTRB ,N)
 0277                DO 925 I=1,N
 0278            925 DUM2(I)=HSTTT(I)
 0279                CALL AVER(DUM,DUM1,DUM2,DUM3,MSFLOS,KB(1),HSTTTB,N)
 0280                DO 926 I=1,N
 0281            926 DUM2(I)=HSTSS(I)
 0282                CALL AVER(DUM,DUM1,DUM2,DUM3,MSFLOS,KB(1),HSTSSB,N)
 0283                DO 927 I=1,N
 0284                DUM(I)=R(I,2)
 0285                DUM1(I)=VAS(I,2)
 0286                DUM2(I)=PTS(I,2)
 0287            927 DUM3(I)=STDEN(I,2)
 0288                CALL AVER(DUM,DUM1,DUM2,DUM3,MSFLOS,KB(2),PTBAR2,N)
 0289                DO 928 I=1,N
 0290            928 DUM2(I)=PS(I,2)
 0291                CALL AVER(DUM,DUM1,DUM2,DUM3,MSFLOS,KB(2),PSBAR2,N)
```

TABLE III (CONT.)

```
      DO 929 I=1,N
  929 DUM2(I)=ETAS(I)
      CALL AVER(DUM,DUM1,DUM2,DUM3,MSFLOS,KB(2),ETSBAR,N)
      DO 930 I=1,N
      DUM(I)=R(I,3)
      DUM1(I)=VAS(I,3)
      DUM2(I)=PTS(I,3)
  930 DUM3(I)=STDEN(I,3)
      CALL AVER(DUM,DUM1,DUM2,DUM3,MSFLOS,KB(3),PTBAR3,N)
      DO 931 I=1,N
  931 DUM2(I)=PS(I,3)
      CALL AVER(DUM,DUM1,DUM2,DUM3,MSFLOS,KB(3),PSBAR3,N)
C***
C***  PRINTOUT OF RESULTS
C***
      DO 384 J=1,3
      WRITE(6,129)J
  129 FORMAT(1X,'STATION ',I2,/,1X,'---------- ',//)
      WRITE(6,128)
  128 FORMAT(1X,'DIMENSIONLESS QUANTITIES'/1X,'------------------------'
     1,//)
      WRITE(6,185)
  185 FORMAT(                                        7X,'R*'14X,'PT*'13X
     1,'PS*'13X,'ROT*'12X,'RO*'13X,'H*'14X,'S*'13X,'TS*'/)
      WRITE(6,901)(R(I,J),PTS(I,J),PS(I,J),ROTS(I,J),STDEN(I,J),HS(I,J)
     2,SS(I,J),TS(I,J),I=1,N)
  901 FORMAT(8(1X,E15.8))
  130 FORMAT(7(1X,E15.8))
      WRITE(6,131)
  131 FORMAT(//,7X,'R*',14X,'V*',14X,'VA*',14X,'VU*',14X,'VR*',12X,'MACH
     1',11X,'ALFA'/)
      WRITE(6,130)(R(I,J),VS(I,J),VAS(I,J),VUS(I,J),VRS(I,J),MACH(I,J),
     1ALFA(I,J),I=1,N)
      WRITE(6,132)
  132 FORMAT(//,7X,'R*',14X,'W*',14X,'WU*',11X,'MACH R',12X'BETA',/)
      WRITE(6,133)(R(I,J),WS(I,J),WUS(I,J),MACHR(I,J),BETA(I,J),I=1,N)
  133 FORMAT(5(1X,E15.8))
      WRITE(6,134)
  134 FORMAT(1X,'DIMENSIONAL QUANTITIES'/1X'----------------------  '//
     1,7X,'R',15X,'PT',14X,'PS',14X,'ROT',13X,'RO',14X,'H',15X,'TS'/)
      DO 135 I=1,N
  135 R(I,J)=R(I,J)*RM
      WRITE(6,130)(R(I,J),PT(I,J),P(I,J),ROT(I,J),RO(I,J),H(I,J),T (I,J
     1),I=1,N)
      WRITE(6,136)
  136 FORMAT(//,7X,'R',15X,'S',14X,'TOT',14X,'V',15X,'VA',14X,'VU',14X,
     1'VP',/)
      WRITE(6,130)(R(I,J),S(I,J),TOT(I,J),V(I,J),VA(I,J),VU(I,J),VR(I,J
     1),I=1,N)
      WRITE(6,137)
  137 FORMAT(//,7X,'R',15X,'U',15X,'W',15X,'WU'/)
      WRITE(6,138)(R(I,J),U(I,J),C(I,J),WU(I,J),I=1,N)
  138 FORMAT(4(1X,E15.8))
  384 CONTINUE
      WRITE(6,932)
  932 FORMAT(1H1,1X,'ROTOR AND STATOR DATA'/1X'---------------------'//)
      WRITE(6,933)
  933 FORMAT(/,20X,'ROTOR'                 /,3X,'STATION', 4X,'LOSS COEF.',
     17X,'D F',13X,'DPTR',10X,'DPSR',10X,'ETAR'//)
      WRITE(6,934)(I,DPTS(I,1),DFAC(I,1),DPTR(I),DPSR(I),ETAR(I),I=1,N)
  934 FORMAT(3X,I2,3X,1X,E15.8,1X,E15.8,1X,E15.8,1X,E15.8,1XE15.8)
      WRITE(6,935)PTBAR1,PSBAR1,PTBAR2,PSBAR2,DPTRB,ETRBAR
  935 FORMAT(/1X,'MASS AVERAGED QUANTITIES'//,5X,'PTBAR1',10X,'PSBAR1',
     110X,'PTBAR2',10X,'PSBAR2',10X,'DPTRB',10X,'ETRBAR'/6(1X,E15.8))
      WRITE(6,936)
  936 FORMAT(/,20X,'STATOR'/,3X,'STATION',4X,'LOSS COEF.',7X,'D F',13X,
     1'DPSS',10X,'ETAS'//)
      WRITE(6,937)(I,DPTS(I,2),DFAC(I,2),DPSS(I),ETAS(I),I=1,N)
  937 FORMAT(3X,I2,3X,1X,E15.8,1X,E15.8,1X,E15.8,1X,E15.8)
      WRITE(6,938)PTBAR2,PTBAR3,PSBAR2,PSBAR3,ETSBAR
  938 FORMAT(/1X,'MASS AVERAGED QUANTITIES'//,5X,'PTBAR2',10X,'PTBAR3',
     110X,'PSBAR2',10X,'PSBAR3',10X,'ETSBAR'/5(1X,E15.8))
      WRITE(6,939)
```

TABLE III (CONT.)

```
0349          939 FORMAT(/,20X,'STAGE'/,3X,'STATION',4X,'ETA T-T',8X,'ETA S-S',12X,
                 1'DPSST'//)
0350              WRITE(6,940)(I,HSTTT(I),HSTSS(I),DPSST(I),I=1,N)
0351          940 FORMAT(3X,I2,3X,1X,E15.8,1X,E15.8,1X,E15.8)
0352              WRITE(6,941)HSTTTB,HSTSSB
0353          941 FORMAT(/1X,'MASS AVERAGED QUANTITIES'//,5X' HSTTTB',8X,'HSTSSB',
                 1/2(1X,E15.8))
0354          950 CONTINUE
0355          100 FORMAT(4E15.8)
0356          101 FORMAT(3I3)
0357          106 FORMAT(2X'ERROR'/)
0358          107 FORMAT(2X,'STATION 'I2//,8X,'R',15X'PT',15X,'ROT',15X,'H ',15X,'S'
                 1,15X,'DH',15X,'T'/)
0359          108 FORMAT(7(1X,E15.8))
0360          109 FORMAT(///8X'R',15X'V',15X,'VA',15X,'VU',15X,'VR',15X,'RO',15X,'MA
                 1CH'/)
0361          110 FORMAT(7(1X,E15.8))
0362              STOP
0363              END
```

TABLE III (CONT.)

```
FORTRAN IV G LEVEL  18              LOSTP              DATE = 71251          17/06/32

              SUBROUTINE LOSTP(ITES2,V1,V2,VU1,VU2,A1,A2,AMACH,SIGM ,GAMA,N)
              COMMON R(11,3),          DFAC(11,2),PTS(11,3),PS(11,3),DPS(11,2)
              DIMENSION V1(11),V2(11),VU1(11),VU2(11),A1(11),A2(11),AMACH(11),
             1SIGM (11)
              PI=3.141593
              IF(ITES2)1,1,2
        C***
        C***  IF ITES2 IS NEGATIVE OR ZERO CALCULATION IS PERFORMED FOR A ROTOR
        C***  IF POSITIVE CALCULATION IS PERFORMED FOR A STATOR.
        C***
            1 J=1
              CONST=0.228
              GO TO 3
            2 J=2
              CONST=0.057
            3 DO 4 I=1,N
              SIGMA=SIGM(I)
              DFAC(I,J)=1.-V2(I)/V1(I)+(R(I,J)*VU1(I)-R(I,J+1)*VU2(I))/(SIGMA*
             1(R(I,J)+R(I,J+1))*V1(I))
              DFAC(I,J)=ABS(DFAC(I,J))
              RR=(R(N,J+1)-R(I,J+1))/(R(N,J+1)-R(1,J+1))
              DPS(I,J)=2*SIGMA/COS(A2(I)/57.29578)*(0.004+0.0639*(DFAC(I,J)+0.1
             1)**2.91+CONST*DFAC(I,J)**2.02*(1.-RR)**3.77)
              IF(A2(I).LT.45.)GO TO 5
              DPS(I,J)=DPS(I,J)*COS(A2(I)/57.29578)*SQRT(2.)*(1.-PI/4.+PI*A2(I)
             1/180.)
            5 DELNI=.625*(A1(I)-A2(I))/SIGMA
              AM=AMACH(I)
              ITES3=0
              IF(AMACH(I).GT.1.)GO TO 6
              AM=1.0001
              ITES3=1
            6 AMSU=1.095+0.03395*DELNI+1.086*(AM-1.)**1.372
              AMM=(AMACH(I)+AMSU)/2.
              IF(AMM.LT.1. .AND. ITES3.EQ.1)GO TO 7
              IF(AMM.GT.1. .AND. ITES3.EQ.1)GO TO 10
              GO TO 9
           10 AMM=1.
            9 Z1=((GAMA+1.)*AMM**2/((GAMA-1.)*AMM**2+2.))**(GAMA/(GAMA-1.))
              Z2=((GAMA+1.)/(2.*GAMA*AMM**2-GAMA+1.))**(1./(GAMA-1.))
              Z3=(1.-(GAMA-1.)/2.*AM**2)**(GAMA/(GAMA-1.))
              DPSSH=(1.-Z1*Z2)/(1.-1./Z3)
              GO TO 8
            7 DPSSH=0.
            8 DPS(I,J)=DPS(I,J)+DPSSH
            4 DPS(I,J)=DPS(I,J)*(PTS(I,J)-PS(I,J))
              RETURN
              END
```

TABLE III (CONT.)

```
FORTRAN IV G LEVEL  18                SUMAT               DATE = 71251          17/06/32                PAGE 0001

                SUBROUTINE SUMAT(N,Y,X,SUM)
                DIMENSION Y(1),X(1),SUM(1),S(3),F(3)
                SUM(1)=0.
                N1=N-2
                DO 1 I=1,N1,2
              1 SUM(I+2)=SUM(I)+TEGP(X(I),X(I+1),X(I+2),Y(I),Y(I+1),Y(I+2))
                DO 2 I=2,N1,2
                DO 3 J=1,3
                J1=I-3+2*J
                S(J)=X(   J1)
              3 F(J)=SUM(J1)
                FF=X(I)
                CALL INTPO(3,FF,S,F)
              2 SUM(I)=F(1)
                DO 4 J=1,3
                J1=N+2*J-6
                S(J)=X(J1)
              4 F(J)=SUM(J1)
                FF=X(N-1)
                CALL INTPO(3,FF,S,F)
                SUM(N-1)=F(1)
                RETURN
                END
```

TABLE III (CONT.)

```
FORTRAN IV G LEVEL  18              INTPO          DATE = 71251          17/06/32            PAGE 0001
                  SUBROUTINE INTPO(NI,XI,X,F)
                  DIMENSION X(1),F(1)
                  J=0
                  NP=NI
                1 NP=NP-1
                  J=J+1
                  DO 2 K=1,NP
                  I=K+J
                2 F(K)=(F(K)*(X(I)-XI)+F(K+1)*(XI-X(K)))/(X(I)-X(K))
                  IF(NP-1) 3,3,1
                3 RETURN
                  END
```

TABLE III (CONT)

```
FORTRAN IV G LEVEL  18                DERIR               DATE = 71251          17/06/32              PAGE 0001

              SUBROUTINE DERIR(N,S,W,DER)
              DIMENSION X(5),Y(5),XX(5),YY(5),F1(4),F2(3),F3(2),S(1),W(1),DER(1)
              DO 80 I=1,2
              XX(I)=S(I)
           80 YY(I)=W(I)
              M=0
              K=0
           25 K=K+1
              DO 10 I=3,5
              L=I+K-1
              XX(I)=S(L)
           10 YY(I)=W(L)
            5 M=M+1
              M1=M-K+1
              X(1)=XX(M1)
              Y(1)=YY(M1)
              IF(M1-1)1,2,1
            1 DO 20 I=2,M1
              J=I-1
              X(I)=XX(J)
           20 Y(I)=YY(J)
            2 IF(M1-5)3,4,4
            3 DO 30 I=M1,4
              J=I+1
              X(J)=XX(J)
           30 Y(J)=YY(J)
            4 DO 40 I=1,4
           40 F1(I)=(Y(I)-Y(I+1))/(X(I)-X(I+1))
              DO 50 I=1,3
           50 F2(I)=(F1(I)-F1(I+1))/(X(I)-X(I+2))
              DO 60 I=1,2
           60 F3(I)=(F2(I)-F2(I+1))/(X(I)-X(I+3))
              F4=(F3(1)-F3(2))/(X(1)-X(5))
              DER(M)=F1(1)+(X(1)-X(2))*F2(1)+(X(1)-X(2))*(X(1)-X(3))*F3(1)+(X(1)
             1-X(2))*(X(1)-X(3))*(X(1)-X(4))*F4
              IF(M-2)6,6,7
            7 IF(M-N+2)8,6,6
            6 IF(M-N)5,15,15
            8 DO 70 I=1,2
              XX(I)=XX(I+1)
           70 YY(I)=YY(I+1)
              GOTO 25
           15 RETURN
              END
```

TABLE III (CONT.)

```
FORTRAN IV G LEVEL  18                ITERN             DATE = 71251          17/06/32                 PAGE 0001

                     SUBROUTINE ITERN(DEB,FIN,DE,EPS,NA1,DEP,X1,X2,X3,F1,F2,NS,NN)
                     IF(NA1) 16,16,17
                  16 NS=0
                     NN=0
                     NA1=1
                     DEP=DE
                     F2=0
                     X2=DEB-DE
                   1 F1=F2
                     X1=X2
                   2 X2=X2+DEP
                     IF(X2-FIN)15,15,12
                  12 NS=-1
                     GO TO 15
                  17 IF(NN)7,10,4
                   4 IF(ABS(F2)-EPS)11,11,13
                  13 IF(F1-F2)5,11,5
                   5 IF(F1*F2)6,11,1
                   6 X3=X2
                     NN=-1
                     DEP=F2*DEP/(F1-F2)
                     GOTO 2
                   7 IF(F1*F2)8,11,9
                   8 DEP=(X1-X2)/10.
                     GOTO 10
                   9 DEP=(X3-X2)/10.
                  10 NN=1
                     GOTO 1
                  11 NS=1
                  15 RETURN
                     END
```

TABLE III (CONT.)

```
FORTRAN IV G LEVEL  18                AVER              DATE = 71251          17/06/32             PAGE 0001
                 SUBROUTINE AVER(R,VA,X,RO,Q,BF,AV,N)
                 DIMENSION R(1),VA(1),RO(1),X(1)
                 DO 1 I=1,N
               1 X(I)=2.*3.1415927*R(I)*VA(I)*RO(I)*X(I)
                 AV=0.
                 N1=N-2
                 DO 2 I=1,N1,2
               2 AV=AV+TEGP(R(I),R(I+1),R(I+2),X(I),X(I+1),X(I+2))
                 AV=AV*BF/Q
                 RETURN
                 END
```

TABLE III (CONT.)

```
FORTRAN IV G LEVEL  18                  TEGP                DATE = 71251          17/06/32                PAGE 0001

 0001                  FUNCTION   TEGP(X1,X2,X3,Y1,Y2,Y3)
 0002                  T1=4.*X2-X3-3.*X1
 0003                  T2= 4.*(X3-X1)
 0004                  T3=3.*X3+X1-4.*X2
 0005                    TEGP=(T1*Y1+T2*Y2+T3*Y3)/6.
 0006                  RETURN
 0007                  END
```

TABLE III (CONT.).

```
 INITIAL DATA
-------------

     RH1                RH2                RH3                RT1                RT2                RT3
0.89999998E 00   0.89999998E 00   0.89999998E 00   0.15000000E 01   0.15000000E 01   0.15000000E 01

     LS                 LR                 RPM                RG                 CURV               GAMA
 .17333329E 00   0.17333329E 00   0.22900000E 04   0.17156299E 04   0.40000000E 01   0.13999996E 01

     KB1                KB2                KB3                PATM               TATM               RO ATM
0.10000000E 01   0.96499997E 00   0.94000000E 00   0.21152300E 04   0.52000000E 03   0.23709950E-02

 MASS FLOW
0.24516134E 01

     S1                 RF                 DH                 H1

0.0              0.50000000E 00   0.30295758E 05   0.31224440E 07
0.0              0.50000000E 00   0.30295758E 05   0.31224440E 07
0.0              0.50000000E 00   0.30295758E 05   0.31224440E 07
0.0              0.50000000E 00   0.30295758E 05   0.31224440E 07
0.0              0.50000000E 00   0.30295758E 05   0.31224440E 07
0.0              0.50000000E 00   0.30295758E 05   0.31224440E 07
0.0              0.50000000E 00   0.30295758E 05   0.31224440E 07
0.0              0.50000000E 00   0.30295758E 05   0.31224440E 07
0.0              0.50000000E 00   0.30295758E 05   0.31224440E 07
```

TABLE IV

```
---------------

ITERATION                  ERROR 1          ERROR 2

        1               0.29635515E-01   0.23034664E-02
        2               0.12412686E-01   0.20497548E-02
        3               0.32600434E-02   0.21798660E-02
        4               0.13279945E-02   0.17845724E-02
        5               0.10278914E-02   0.14815584E-02
        6               0.91367913E-03   0.13191663E-02
        7               0.81977621E-03   0.11817061E-02
        8               0.72476291E-03   0.10612749E-02
        9               0.63861324E-03   0.95373346E-03
       10               0.56216074E-03   0.85794274E-03
       11               0.49772696E-03   0.77481405E-03
       12               0.43983618E-03   0.69222972E-03
       13               0.38991333E-03   0.62318969E-03
       14               0.34254510E-03   0.56337006E-03
       15               0.30800607E-03   0.50483923E-03
       16               0.27142046E-03   0.45423303E-03
       17               0.24246731E-03   0.40801545E-03
       18               0.21374314E-03   0.36785519E-03
       19               0.19154020E-03   0.32942556E-03
       20               0.17210936E-03   0.29671541E-03
STATION  1
----------

DIMENSIONLESS QUANTITIES
-------------------------

      R*               PT*               PS*               ROT*               RO*               H*               S*                TS*

 .75000006E 00    0.10000000E 01    0.95850873E 00    0.99999988E 00    0.97018385E 00    0.37705460E 02    0.0              0.98796475E 00
 .81250000E 00    0.10000000E 01    0.95923561E 00    0.99999988E 00    0.97070968E 00    0.37705460E 02    0.0              0.98817837E 00
 .87499994E 00    0.10000000E 01    0.96026164E 00    0.99999988E 00    0.97145104E 00    0.37705460E 02    0.0              0.98848075E 00
 .93749988E 00    0.10000000E 01    0.96159047E 00    0.99999988E 00    0.97241098E 00    0.37705460E 02    0.0              0.98887092E 00
 .99999982E 00    0.10000000E 01    0.96309918E 00    0.99999988E 00    0.97349399E 00    0.37705460E 02    0.0              0.98931038E 00
 .10624990E 01    0.10000000E 01    0.96486348E 00    0.99999988E 00    0.97477412E 00    0.37705460E 02    0.0              0.98983103E 00
 .11249981E 01    0.10000000E 01    0.96645260E 00    0.99999988E 00    0.97592068E 00    0.37705460E 02    0.0              0.99029726E 00
 .11874971E 01    0.10000000E 01    0.96799141E 00    0.99999988E 00    0.97696525E 00    0.37705460E 02    0.0              0.99072075E 00
 .12500000E 01    0.10000000E 01    0.96924967E 00    0.99999988E 00    0.97793746E 00    0.37705460E 02    0.0              0.99111468E 00

      R*               V*                VA*               VU*                VR*               MACH             ALFA

 .75000006E 00    0.95265883E 00    0.94359416E 00    0.13110650E 00    0.0               0.24679399E 00    0.79102430E 01
 .81250000E 00    0.94415206E 00    0.92674476E 00    0.18646373E 00    0.38464903E-03    0.24456376E 00    0.11019225E 02
 .87499994E 00    0.93220916E 00    0.90383530E 00    0.22742659E 00    0.32712100E-03    0.24138153E 00    0.14123778E 02
 .93749988E 00    0.91609138E 00    0.87459153E 00    0.27260423E 00   -0.15984783E-03    0.23721212E 00    0.17311890E 02
 .99999982E 00    0.89779782E 00    0.84035993E 00    0.31596774E 00   -0.77185757E-03    0.23242348E 00    0.20605804E 02
 .10624990E 01    0.87566566E 00    0.79932845E 00    0.35757560E 00   -0.20472135E-02    0.22663432E 00    0.24101105E 02
 .11249981E 01    0.85536414E 00    0.75689554E 00    0.39843696E 00   -0.22550311E-02    0.22132790E 00    0.27762726E 02
 .11874971E 01    0.83648533E 00    0.71218556E 00    0.43874514E 00   -0.15242666E-02    0.21639669E 00    0.31635330E 02
 .12500000E 01    0.81953896E 00    0.66399318E 00    0.47866392E 00    0.0               0.21171188E 00    0.35787323E 02

      R*               W*                WU*               MACH R             BETA

 .75000006E 00    0.11284494E 01    0.61889356E 00    0.29233396E 00    0.33260437E 02
 .81250000E 00    0.11217528E 01    0.63203627E 00    0.29056716E 00    0.34293823E 02
 .87499994E 00    0.11118765E 01    0.64757335E 00    0.28796548E 00    0.35620544E 02
 .93749988E 00    0.10986338E 01    0.66489565E 00    0.28447950E 00    0.37243378E 02
 .99999982E 00    0.10835609E 01    0.68403208E 00    0.28051418E 00    0.39144714E 02
 .10624990E 01    0.10657616E 01    0.70492345E 00    0.27583373E 00    0.41408890E 02
 .11249981E 01    0.10491838E 01    0.72656113E 00    0.27147931E 00    0.43828537E 02
 .11874971E 01    0.10333673E 01    0.74875200E 00    0.26732856E 00    0.46433762E 02
 .12500000E 01    0.10177659E 01    0.77133608E 00    0.26324099E 00    0.49276947E 02
DIMENSIONAL QUANTITIES
-----------------------

      R                PT                PS                ROT                RO                H                 TS

 .89999992E 00    0.21152300E 04    0.20274663E 04    0.23709945E-02    0.23003009E-02    0.31224440E 07    0.51374170E 03
 .97499985E 00    0.21152300E 04    0.20290039E 04    0.23709945E-02    0.23015477E-02    0.31224440E 07    0.51385278E 03
 .10499992E 01    0.21152300E 04    0.20311741E 04    0.23709945E-02    0.23033055E-02    0.31224440E 07    0.51401001E 03
 .11249990E 01    0.21152300E 04    0.20339849E 04    0.23709945E-02    0.23055815E-02    0.31224440E 07    0.51421289E 03
 .11999989E 01    0.21152300E 04    0.20371570E 04    0.23709945E-02    0.23081494E-02    0.31224440E 07    0.51444141E 03
 .12749977E 01    0.21152300E 04    0.20409080E 04    0.23709945E-02    0.23111845E-02    0.31224440E 07    0.51471210E 03
 .13499966E 01    0.21152300E 04    0.20442633E 04    0.23709945E-02    0.23139028E-02    0.31224440E 07    0.51495459E 03
 .14249954E 01    0.21152300E 04    0.20473340E 04    0.23709945E-02    0.23163797E-02    0.31224440E 07    0.51517480E 03
 .14999990E 01    0.21152300E 04    0.20501358E 04    0.23709945E-02    0.23186847E-02    0.31224440E 07    0.51537964E 03
```

```
       R                S                         TOT              V                VA               VU               VR

0.89999992E 00   0.0                       0.52000000E 03   0.27414624E 03   0.27153784E 03   0.37728485E 02   0.0
0.97499985E 00   0.0                       0.52000000E 03   0.27169824E 03   0.26668896E 03   0.51932007E 02   0.11069036E 00
0.10499992E 01   0.0                       0.52000000E 03   0.26820386E 03   0.26009644E 03   0.65446487E 02   0.94135523E-01
0.11249990E 01   0.0                       0.52000000E 03   0.26362329E 03   0.25168100E 03   0.78447250E 02  -0.45999371E-01
0.11999989E 01   0.0                       0.52000000E 03   0.25835889E 03   0.24183018E 03   0.90925964E 02  -0.22211725E 00
0.12749977E 01   0.0                       0.52000000E 03   0.25199010E 03   0.23002255E 03   0.10289944E 03  -0.58912611E 00
0.13499966E 01   0.0                       0.52000000E 03   0.24614793E 03   0.21781165E 03   0.11465811E 03  -0.64892977E 00
0.14249954E 01   0.0                       0.52000000E 03   0.24071518E 03   0.20494547E 03   0.12625758E 03  -0.43863779E 00
0.14999990E 01   0.0                       0.52000000E 03   0.23555077E 03   0.19107716E 03   0.13774500E 03   0.0

       R                U                W                WU

0.89999992E 00   0.21582735E 03   0.32473340E 03   0.17809886E 03
0.97499985E 00   0.23381294E 03   0.32280591E 03   0.18188092E 03
0.10499992E 01   0.25179852E 03   0.31996436E 03   0.18635204E 03
0.11249990E 01   0.26978394E 03   0.31615356E 03   0.19133687E 03
0.11999989E 01   0.28776953E 03   0.31181592E 03   0.19684375E 03
0.12749977E 01   0.30575488E 03   0.30669385E 03   0.20285565E 03
0.13499966E 01   0.32374023E 03   0.30192334E 03   0.20908232E 03
0.14249954E 01   0.34172559E 03   0.29737061E 03   0.21546819E 03
0.14999990E 01   0.35971216E 03   0.29288184E 03   0.22196721E 03
STATION  2
----------

DIMENSIONLESS QUANTITIES
------------------------

       R*               PT*              PS*              ROT*             RO*              H*               S*               TS*

0.75000006E 00   0.10335846E 01   0.96956897E 00   0.10236521E 01   0.97795427E 00   0.38071289E 02   0.21685603E-03   0.99142361E 00
0.81147295E 00   0.10335894E 01   0.97175288E 00   0.10236559E 01   0.97952884E 00   0.38071289E 02   0.21545851E-03   0.99205977E 00
0.87334627E 00   0.10335970E 01   0.97368771E 00   0.10236645E 01   0.98092347E 00   0.38071289E 02   0.21334527E-03   0.99262178E 00
0.93579358E 00   0.10335913E 01   0.97536826E 00   0.10236588E 01   0.98213065E 00   0.38071289E 02   0.21482795E-03   0.99311286E 00
0.99811995E 00   0.10335350E 01   0.97699189E 00   0.10236025E 01   0.98328215E 00   0.38071289E 02   0.23042248E-03   0.99359971E 00
0.10598860E 01   0.10334158E 01   0.97832119E 00   0.10234842E 01   0.98420507E 00   0.38071289E 02   0.26335265E-03   0.99401897E 00
0.11224251E 01   0.10331316E 01   0.98014671E 00   0.10232029E 01   0.98543954E 00   0.38071289E 02   0.34202891E-03   0.99462700E 00
0.11857805E 01   0.10325594E 01   0.98235023E 00   0.10226364E 01   0.98686522E 00   0.38071289E 02   0.50021429E-03   0.99542236E 00
0.12500000E 01   0.10314379E 01   0.98465484E 00   0.10215254E 01   0.98821157E 00   0.38071289E 02   0.81088766E-03   0.99639845E 00

       R*               V*               VA*              VU*              VR*              MACH             ALFA

0.75000006E 00   0.11740360E 01   0.99766350E 00   0.61889315E 00   0.0              0.30361253E 00   0.31813080E 02
0.81147295E 00   0.11534166E 01   0.96516776E 00   0.63152415E 00   0.40059676E-03   0.29818445E 00   0.33197327E 02
0.87334627E 00   0.11349030E 01   0.93258911E 00   0.64674830E 00   0.33752783E-03   0.29331529E 00   0.34741196E 02
0.93579358E 00   0.11184807E 01   0.90002668E 00   0.66404229E 00  -0.16449658E-03   0.28899950E 00   0.36419998E 02
0.99811995E 00   0.11019239E 01   0.86465162E 00   0.68309212E 00  -0.79416926E-03   0.28465164E 00   0.38309433E 02
0.10598860E 01   0.10874853E 01   0.82917976E 00   0.70362091E 00  -0.21236676E-02   0.28086251E 00   0.40317078E 02
0.11224251E 01   0.10662107E 01   0.78151739E 00   0.72528023E 00  -0.23283875E-02   0.27528387E 00   0.42862579E 02
0.11857805E 01   0.10376892E 01   0.71933788E 00   0.74789739E 00  -0.15395745E-02   0.26781297E 00   0.46115082E 02
0.12500000E 01   0.10015974E 01   0.63893545E 00   0.77133608E 00   0.0              0.25837147E 00   0.50363342E 02

       R*               W*               WU*              MACH R           BETA

0.75000006E 00   0.10062408E 01   0.13110691E 00   0.26021969E 00   0.74865627E 01
0.81147295E 00   0.98179960E 00   0.17994881E 00   0.25381756E 00   0.10561138E 02
0.87334627E 00   0.95972347E 00   0.22659796E 00   0.24804026E 00   0.13656918E 02
0.93579358E 00   0.94015783E 00   0.27175128E 00   0.24292338E 00   0.16800995E 02
0.99811995E 00   0.92025292E 00   0.31502783E 00   0.23772198E 00   0.20018738E 02
0.10598860E 01   0.90247893E 00   0.35626507E 00   0.23308134E 00   0.23251236E 02
0.11224251E 01   0.87654062E 00   0.39714485E 00   0.22633892E 00   0.26938370E 02
0.11857805E 01   0.84213471E 00   0.43788314E 00   0.21734309E 00   0.31330154E 02
0.12500000E 01   0.79834682E 00   0.47866392E 00   0.20594108E 00   0.36839020E 02
DIMENSIONAL QUANTITIES
----------------------

       R                PT               PS               ROT              RO               H                TS

0.89999992E 00   0.21862690E 04   0.20508613E 04   0.24270739E-02   0.23187245E-02   0.31527390E 07   0.51554028E 03
0.97376734E 00   0.21862791E 04   0.20554807E 04   0.24270830E-02   0.23224580E-02   0.31527390E 07   0.51587109E 03
0.10480146E 01   0.21862952E 04   0.20595732E 04   0.24271032E-02   0.23257646E-02   0.31527390E 07   0.51616333E 03
0.11229515E 01   0.21862832E 04   0.20631282E 04   0.24270897E-02   0.23286268E-02   0.31527390E 07   0.51641870E 03
0.11977434E 01   0.21861641E 04   0.20665625E 04   0.24269563E-02   0.23313570E-02   0.31527390E 07   0.51667188E 03
0.12718620E 01   0.21859119E 04   0.20693743E 04   0.24266760E-02   0.23335451E-02   0.31527390E 07   0.51688989E 03
0.13469095E 01   0.21853108E 04   0.20732356E 04   0.24260089E-02   0.23364720E-02   0.31527390E 07   0.51720605E 03
0.14229355E 01   0.21841006E 04   0.20778965E 04   0.24246657E-02   0.23398525E-02   0.31527390E 07   0.51761963E 03
0.14999990E 01   0.21817283E 04   0.20827712E 04   0.24220315E-02   0.23430446E-02   0.31527390E 07   0.51812720E 03
```

```
      R                S               ROT               V               VA               VU              VR

 0.89999992E 00  0.13021545E 01  0.52504517E 03  0.33785205E 03  0.28709717E 03  0.17809874E 03  0.0
 0.97376734E 00  0.12937632E 01  0.52504517E 03  0.33191821E 03  0.27774609E 03  0.18173355E 03  0.11527961E 00
 0.10480146E 01  0.12810736E 01  0.52504517E 03  0.32659058E 03  0.26837085E 03  0.18611461E 03  0.97130299E-01
 0.11229515E 01  0.12899771E 01  0.52504517E 03  0.32186475E 03  0.25900024E 03  0.19109129E 03 -0.47337141E-01
 0.11977434E 01  0.13836174E 01  0.52504517E 03  0.31710034E 03  0.24882060E 03  0.19657326E 03 -0.22853786E 00
 0.12718620E 01  0.15813532E 01  0.52504517E 03  0.31294531E 03  0.23861287E 03  0.20248082E 03 -0.61112732E 00
 0.13469095E 01  0.20537806E 01  0.52504517E 03  0.30682300E 03  0.22489708E 03  0.20871371E 03 -0.67003953E 00
 0.14229355E 01  0.30036354E 01  0.52504517E 03  0.29861548E 03  0.20700369E 03  0.21522226E 03 -0.44304299E 00
 0.14999990E 01  0.48691359E 01  0.52504517E 03  0.28822925E 03  0.18386630E 03  0.22196721E 03  0.0

      R                U                W               WU

 0.89999992E 00  0.21582735E 03  0.28956567E 03  0.37728592E 02
 0.97376734E 00  0.23351738E 03  0.28253223E 03  0.51783813E 02
 0.10480146E 01  0.25132265E 03  0.27617920E 03  0.65208038E 02
 0.11229515E 01  0.26929297E 03  0.27054883E 03  0.78201797E 02
 0.11977434E 01  0.28722852E 03  0.26482080E 03  0.90655487E 02
 0.12718620E 01  0.30500293E 03  0.25970605E 03  0.10252231E 03
 0.13469095E 01  0.32300000E 03  0.25227066E 03  0.11428629E 03
 0.14229355E 01  0.34123169E 03  0.24234091E 03  0.12600952E 03
 0.14999990E 01  0.35971216E 03  0.22974008E 03  0.13774500E 03
STATION   3
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DIMENSIONLESS QUANTITIES
------------------------

      R*              PT*              PS*             ROT*              RO*              H*               S*              TS*

 0.75000006E 00  0.10322978E 01  0.98647034E 00  0.10221786E 01  0.98969418E 00  0.38071289E 02  0.62815147E-03  0.99674165E 00
 0.81264514E 00  0.10322924E 01  0.98725206E 00  0.10223713E 01  0.99030715E 00  0.38071289E 02  0.57421415E-03  0.99691254E 00
 0.87512547E 00  0.10324268E 01  0.98837316E 00  0.10225048E 01  0.99114698E 00  0.38071289E 02  0.53699431E-03  0.99719942E 00
 0.93743271E 00  0.10324907E 01  0.98978800E 00  0.10225677E 01  0.99217820E 00  0.38071289E 02  0.51921234E-03  0.99758911E 00
 0.99967295E 00  0.10324554E 01  0.99143738E 00  0.10225334E 01  0.99334860E 00  0.38071289E 02  0.52902754E-03  0.99807316E 00
 0.10615940E 01  0.10322876E 01  0.99325734E 00  0.10223665E 01  0.99460489E 00  0.38071289E 02  0.57544280E-03  0.99864310E 00
 0.11239462E 01  0.10319128E 01  0.99505341E 00  0.10219965E 01  0.99578506E 00  0.38071289E 02  0.67930087E-03  0.99926287E 00
 0.11867418E 01  0.10311188E 01  0.99671656E 00  0.10212784E 01  0.99677414E 00  0.38071289E 02  0.87994384E-03  0.99993986E 00
 0.12500000E 01  0.10298234E 01  0.99800462E 00  0.10199261E 01  0.99731678E 00  0.38071289E 02  0.12584946E-02  0.10006866E 01

      R*               V*              VA*              VU*              VR*             MACH             ALFA

 0.75000006E 00  0.98860580E 00  0.97987372E 00  0.13110650E 00  0.0             0.25497627E 00  0.76208782E 01
 0.81264514E 00  0.98275519E 00  0.96533161E 00  0.18046373E 00  0.40066475E-03  0.25326496E 00  0.10588917E 02
 0.87512547E 00  0.97598082E 00  0.94397080E 00  0.22742659E 00  0.34164707E-03  0.25037301E 00  0.13545856E 02
 0.93743271E 00  0.95572937E 00  0.91602707E 00  0.27260423E 00 -0.16742095E-03  0.24639207E 00  0.16572693E 02
 0.99967295E 00  0.93644184E 00  0.88152146E 00  0.31596774E 00 -0.80966763E-03  0.24136120E 00  0.19719345E 02
 0.10615940E 01  0.91320437E 00  0.84028411E 00  0.35757560E 00 -0.21521077E-02  0.23530471E 00  0.23051743E 02
 0.11239462E 01  0.88725370E 00  0.79275572E 00  0.39843696E 00 -0.23618699E-02  0.22854716E 00  0.26683975E 02
 0.11867418E 01  0.85800368E 00  0.73734027E 00  0.43874514E 00 -0.15781042E-02  0.22093779E 00  0.30754227E 02
 0.12500000E 01  0.82448107E 00  0.67130464E 00  0.47866392E 00  0.0             0.21222633E 00  0.35490204E 02

      R*               W*              WU*             MACH R            BETA

 0.75000006E 00  0.11589575E 01  0.61889356E 00  0.29891253E 00  0.32276718E 02
 0.81264514E 00  0.11539145E 01  0.63218141E 00  0.29758626E 00  0.33220184E 02
 0.87512547E 00  0.11448116E 01  0.64769888E 00  0.29519629E 00  0.34455673E 02
 0.93743271E 00  0.11318579E 01  0.66482848E 00  0.29179895E 00  0.35971146E 02
 0.99967295E 00  0.11159015E 01  0.68370521E 00  0.28753543E 00  0.37796906E 02
 0.10615940E 01  0.10962315E 01  0.70401841E 00  0.28246516E 00  0.39957397E 02
 0.11239462E 01  0.10746298E 01  0.72550923E 00  0.27681327E 00  0.42463913E 02
 0.11867418E 01  0.10503197E 01  0.74799669E 00  0.27045959E 00  0.45411011E 02
 0.12500000E 01  0.10225496E 01  0.77133608E 00  0.26321036E 00  0.48966446E 02
DIMENSIONAL QUANTITIES
----------------------

      R                PT               PS              ROT               RO               H               TS

 0.89999992E 00  0.21831240E 04  0.20866116E 04  0.24235803E-02  0.23465599E-02  0.31527390E 07  0.51830566E 03
 0.97517395E 00  0.21835356E 04  0.20882651E 04  0.24240371E-02  0.23480132E-02  0.31527390E 07  0.51839453E 03
 0.10501499E 01  0.21838201E 04  0.20906365E 04  0.24243537E-02  0.23500044E-02  0.31527390E 07  0.51854370E 03
 0.11249189E 01  0.21839559E 04  0.20936292E 04  0.24245030E-02  0.23524493E-02  0.31527390E 07  0.51874634E 03
 0.11996069E 01  0.21838806E 04  0.20971179E 04  0.24244215E-02  0.23552245E-02  0.31527390E 07  0.51899805E 03
 0.12739124E 01  0.21835256E 04  0.21009675E 04  0.24240259E-02  0.23582031E-02  0.31527390E 07  0.51929443E 03
 0.13487349E 01  0.21827327E 04  0.21047666E 04  0.24231484E-02  0.23610312E-02  0.31527390E 07  0.51961670E 03
 0.14240894E 01  0.21811947E 04  0.21082847E 04  0.24214459E-02  0.23633463E-02  0.31527390E 07  0.51996875E 03
 0.14999990E 01  0.21783130E 04  0.21110093E 04  0.24182396E-02  0.23646329E-02  0.31527390E 07  0.52035742E 03
```

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      R              S              TOT             V              VA             VU             VR

0.89999992E 00  0.37718601E 01  0.52504517E 03  0.28449072E 03  0.28197803E 03  0.37728485E 02  0.0
0.97517395E 00  0.34479828E 01  0.52504517E 03  0.28260571E 03  0.27779321E 03  0.51932007E 02  0.11529917E 00
0.10501499E 01  0.32244892E 01  0.52504517E 03  0.27941870E 03  0.27164624E 03  0.65446487E 02  0.98315656E-01
0.11249189E 01  0.31177130E 01  0.52504517E 03  0.27502979E 03  0.26360474E 03  0.78447250E 02 -0.48178688E-01
0.11996069E 01  0.31766510E 01  0.52504517E 03  0.26947949E 03  0.25367638E 03  0.90925964E 02 -0.23299783E 00
0.12739124E 01  0.34553604E 01  0.52504517E 03  0.26279248E 03  0.24180836E 03  0.10289944E 03 -0.61931151E 00
0.13487349E 01  0.40789967E 01  0.52504517E 03  0.25532478E 03  0.22813113E 03  0.11465811E 03 -0.67967474E 00
0.14240894E 01  0.52837973E 01  0.52504517E 03  0.24690752E 03  0.21218423E 03  0.12625758E 03 -0.45413065E 00
0.14999990E 01  0.75568810E 01  0.52504517E 03  0.23726073E 03  0.19318118E 03  0.13774500E 03  0.0

      R              U              W               WU

0.89999992E 00  0.21582735E 03  0.33351270E 03  0.17809886E 03
0.97517395E 00  0.23385471E 03  0.33206152E 03  0.18192270E 03
0.10501499E 01  0.25183466E 03  0.32944214E 03  0.18638815E 03
0.11249189E 01  0.26976465E 03  0.32571436E 03  0.19131754E 03
0.11996069E 01  0.28767554E 03  0.32103296E 03  0.19674969E 03
0.12739124E 01  0.30549463E 03  0.31546216E 03  0.20259521E 03
0.13487349E 01  0.32343750E 03  0.30924585E 03  0.20877962E 03
0.14240894E 01  0.34150839E 03  0.30225024E 03  0.21525082E 03
0.14999990E 01  0.35971216E 03  0.29425879E 03  0.22196721E 03
```

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ROTOR AND STATOR DATA
---------------------


                ROTOR
STATION    LOSS COFF.         D F                 DPTR             DPSR             ETAR

  1        .78478782E-03  0.31194323E 00  0.33584595E-01  0.11060238E-01  0.97744977E 00
  2       0.77975797E-03  0.32253993E 00  0.33589363E-01  0.12517273E-01  0.97754657E 00
  3       0.77212648E-03  0.32943541E 00  0.33596992E-01  0.13426065E-01  0.97774011E 00
  4       0.77748764E-03  0.33202606E 00  0.33591270E-01  0.13777792E-01  0.97764331E 00
  5       0.83391694E-03  0.33467168E 00  0.33535004E-01  0.13901711E-01  0.97594965E 00
  6       0.95300120E-03  0.33461540E 00  0.33415794E-01  0.13457716E-01  0.97261065E 00
  7        .12375191E-02  0.34270734E 00  0.33131599E-01  0.13694108E-01  0.96433580E 00
  8       0.18093716E-02  0.35941404E 00  0.32559395E-01  0.14448822E-01  0.94788289E 00
  9       0.29315236E-02  0.38496536E 00  0.31437874E-01  0.15405178E-01  0.91563698E 00
MASS AVERAGED QUANTITIES

   PTBAR1          PSBAR1           PTBAR2           PSBAR2           DPTRB            ETRBAR
 .10000000E 01  0.96355259E 00  0.10332413E 01  0.97713470E 00  0.33245191E-01  0.96764785E 00

                STATOR
STATION    LOSS COEF.         D F                 DPSS             ETAS

  1       0.14867329E-02  0.32745349E 00  0.16901374E-01  0.92298985E 00
  2       0.12963191E-02  0.32455187E 00  0.15499175E-01  0.92635351E 00
  3       0.11701181E-02  0.32659571E 00  0.14685452E-01  0.92958331E 00
  4       0.11605725E-02  0.33448404E 00  0.14410734E-01  0.93220943E 00
  5       0.11793130E-02  0.34597123E 00  0.14445484E-01  0.93341947E 00
  6       0.11280926E-02  0.36322343E 00  0.14936149E-01  0.93266302E 00
  7       0.12186270E-02  0.37933567E 00  0.14906704E-01  0.92725354E 00
  8       0.13709285E-02   .39514697E 00  0.14366329E-01  0.91600585E 00
  9        .16144589E-02   .41171598E 00   .13349771E-01  0.89547426E 00
MASS AVERAGED QUANTITIES

   PTBAR2          PTBAR3           PSBAR2           PSBAR3           ETSBAR
 .10332413E 01  0.1032[illegible]63E 01  0.97713470E 00  0.99191024E 00  0.92616859E 00

                STAGE
STATION    ETA T-T           ETA S-S              DPSST

  1        0.93462372E 00  0.95330048E 00  0.27961612E-01
  2         .94028550E 00  0.95903885E 00  0.28016448E-01
  3        0.94410837E 00  0.96390483E 00  0.28111517E-01
  4        0.94589883E 00  0.96515597E 00  0.28197527E-01
  5        0.94493113E 00  0.96597725E 00  0.28347194E-01
  6        0.94004351E 00  0.96462250E 00  0.28393865E-01
  7        0.92925233E 00  0.96234810E 00  0.28600812E-01
  8        0.90844423E 00  0.95880014E 00  0.28815150E-01
  9        0.86915070E 00  0.95306289E 00  0.28754950E-01
MASS AVERAGED QUANTITIES

   ESTTTB          HSTSSB
 .93217355E 00   0.96173334E 00
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13. ABSTRACT

A computer program is presented to determine the three-dimensional flow conditions in an axial flow compressor stage. Entropy and energy gradients are taken into account as well as the radial shift and the curvatures of the axisymmetric stream surfaces. The program can be used at elevated Mach numbers since shock losses and compressibility effects are included. It represents an extension of work done for a research program to investigate the tip clearance effects in a three-stage compressor, supported by: Naval Air Systems Command, Code 310, AIRTASK No. A310310A/551A/1 R010-03-010.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Axial compressor stage Computer Program Three-Dimensional Flow conditions Entropy and Energy Gradients						